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16. ABSTRACT

Research Outlook 1981 is the sixth in a series of EPA annual reports mandated by Congress. It describes the research we are currently performing and the program we expect to implement over the next five years.

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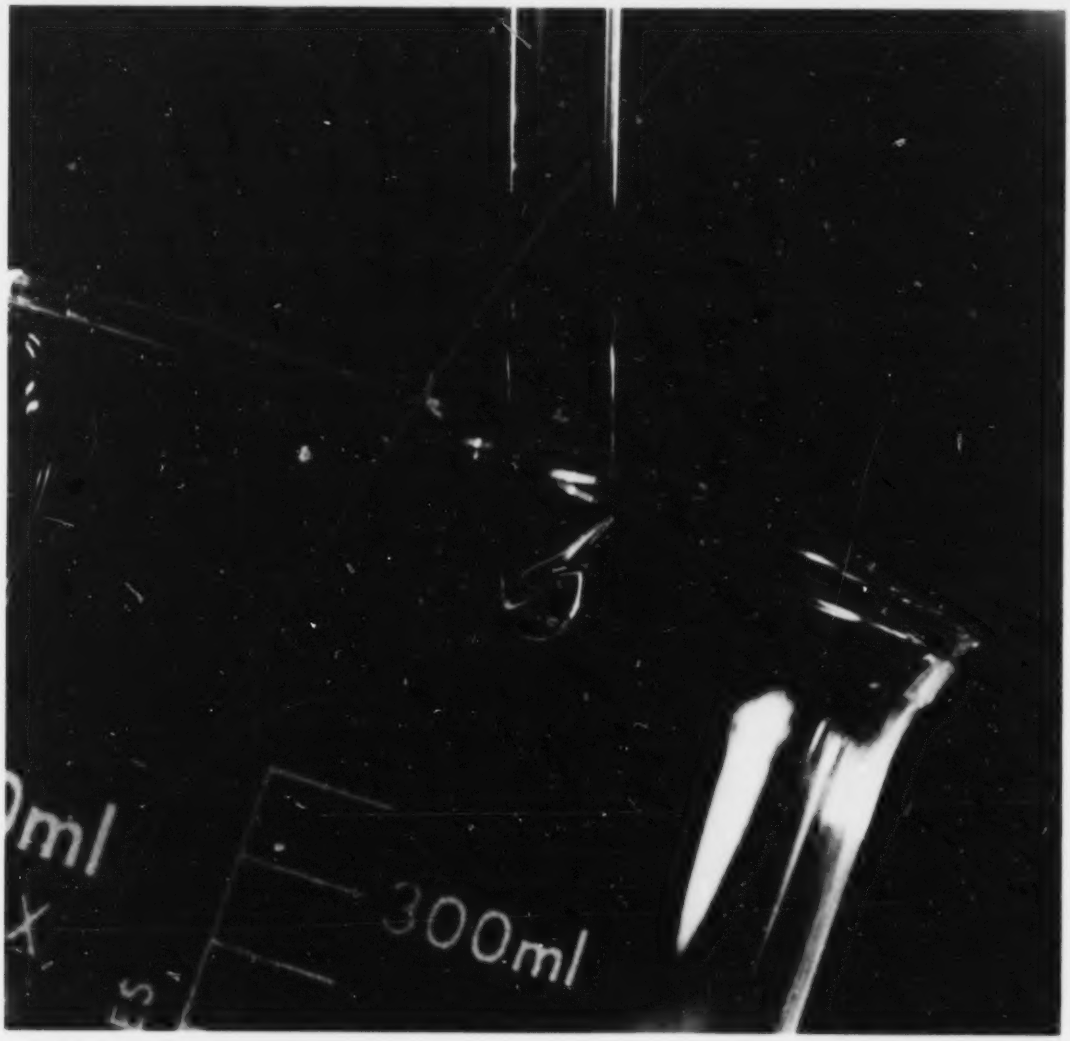
INTRODUCTORY OVERVIEW



Purpose of This Year's Outlook

Research Outlook 1981 is the sixth in a series of annual reports to the Congress. It describes in broad detail the direction EPA's environmental research program will take in the coming five years. The document is written primarily for EPA policy makers, members of Congress and their staffs, and those in the general public who are concerned about the social and economic policy implications of future environmental research.

The primary mission of EPA's Office of Research and Development (ORD) is to support regulatory officials by anticipating their requirements for environmental research data and by initiating, in advance of when the regulatory decisions are to be made, research projects capable of producing the necessary information. EPA spends about $350 million annually for its environmental research program; approximately 85 percent of the total

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supports relatively short-term research on problems of immediate concern to the Agency's regulatory progress. The remaining 15 percent funds longer-term research on more fundamental, or exploratory, scientific issues. Such longer-term research is aimed at anticipating future environmental problems and examining new approaches to environmental management.

Research Outlook 1981 focuses primarily on the work to be performed between 1981 and 1985 in support of regulatory decision making; secondary attention is given to the longer-range efforts that may produce results beyond 1985.

Structure of ORD

The Office of Research and Development is one of six major components of the EPA, each of which is headed by an Assistant Administrator who reports directly to the EPA Administrator. ORD performs multi-disciplinary research in each of the areas over which EPA has regulatory authority, with one exception: a small noise research program housed in the Office of Air, Noise and Radiation.

ORD is divided into four major scientific/technical subdivisions: health effects, environmental processes, engineering, and monitoring. Each is directed by a Deputy Assistant Administrator (DAA). In addition, there are four special-purpose offices: program management, health and environmental assessment, exploratory research, and a senior science advisory staff. These are each headed by an Office Director. The 15 EPA laboratories around the country report directly to the individual DAA's. The laboratories are staffed by some 1150 scientists and engineers who conduct research of their own as well as oversee research by non-government contractors and research carried out for EPA by other federal agencies under joint agreements. The division of ORD along the four scientific/technical lines has evolved over the ten years since the Agency's inception. The nucleus of EPA's research capability was drawn from a variety of pre-existing federal agencies: the Federal Water Quality Administration in the Department of the Interior; the National Air Pollution Control Administration, the Bureaus of Solid Waste Management, Water Hygiene, and Radiological Health in the former Department of Health, Education and Welfare (DHEW); pesticides research and standard setting programs in DHEW's Food and Drug Administration; pesticides registration authority in the Department of Agriculture; and environmental radiation protection programs and authorities in the Atomic Energy Commission and the Federal Radiation Council.

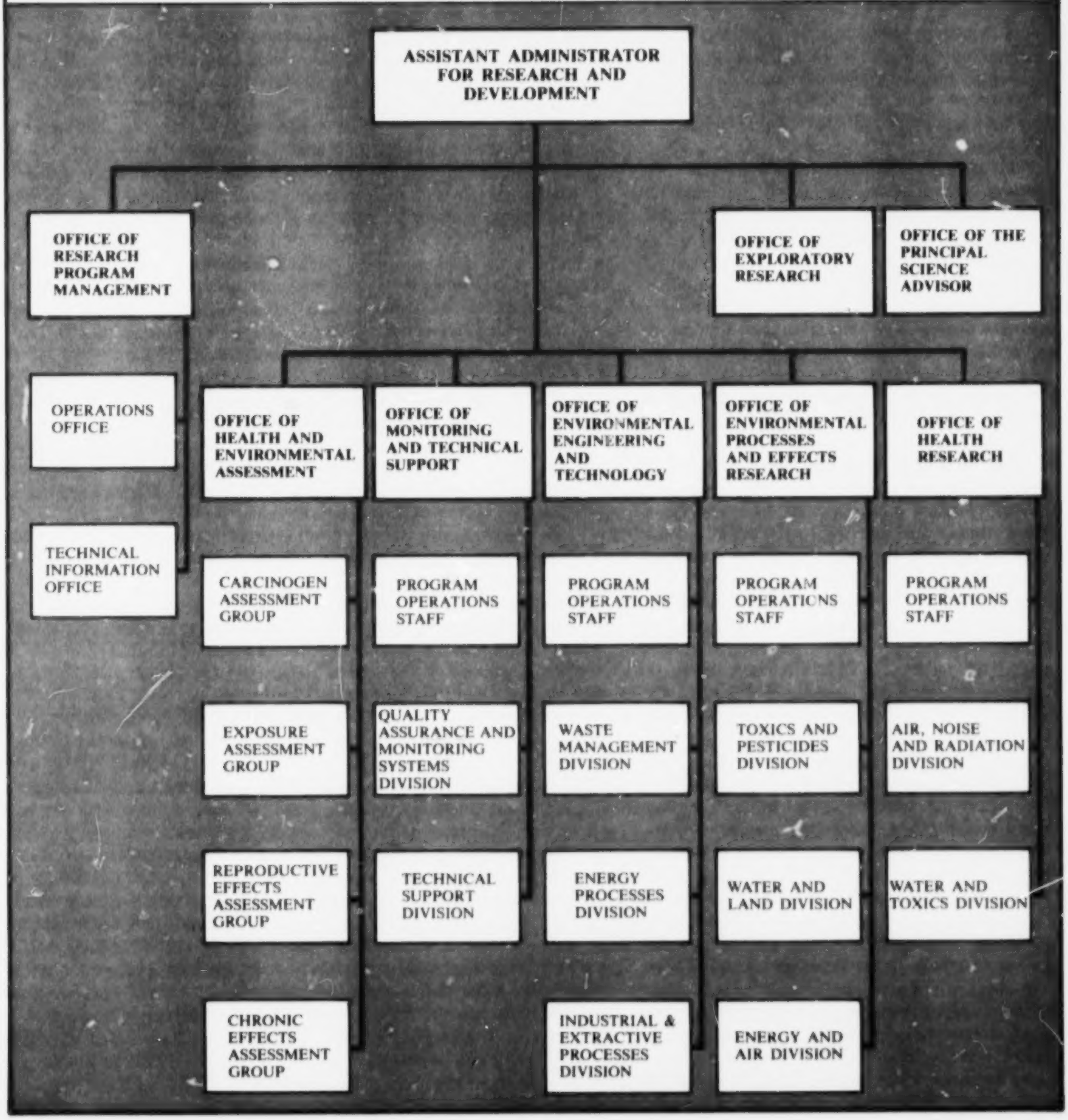
The initial EPA research office was a hybrid organization, combining both a scientific/technical focus and a program/media focus. In Agency parlance, this term "media" has a specific connotation. Initially applied to the environmental substances through which pollutants are transmitted, e.g., air and water, "media" has come to include all of the environmental areas for which EPA has statutory responsibility: air, water quality, drinking water, solid waste, pesticides, radiation, noise, toxic substances, and energy. These "media" are the key organizing principle of the regulatory components of EPA.

This dual focus—scientific/technical and program/media—was a challenge to establishing and maintaining an effective office management structure that would consistently produce rapid responses to requirements for research data. Over the past decade, an evolutionary series of reorganizations and consolidations has improved both the management effectiveness and our responses to changing Agency priorities. The evolutionary process reached a conclusion this year, by clearly delineating responsibilities among the DAA's along scientific/technical lines and by organizing thirteen research planning committees to correspond with the media orientation of the Agency's regulatory and enforcement offices. The committees, composed of EPA regulatory and multi-disciplinary research personnel, meet regularly to plan and oversee research conducted in support of specific areas of regulatory concern.

The genesis and operation of EPA's research committee system is explained more fully in Chapter 1. Described below are the research offices that correspond to the four scientific/technical areas; two special-purpose offices are also discussed.

Office of Health Research. The health research program is directed by the DAA for health effects research. The program, which is conducted primarily at two health effects laboratories, responds to a variety of programmatic needs of EPA by conducting two principal types of research: (1) toxicological, clinical, and epidemiological studies to determine the possible adverse human health effects of pollutants at environmental exposure levels; and (2) development of test methods to provide faster, less expensive, and more reliable determinations than are now available of the health effects of pollutants. Of particular interest are short-term methods to estimate chronic and irreversible effects of exposure to levels of pollutants found in the environment.

US EPA OFFICE OF RESEARCH & DEVELOPMENT HEADQUARTERS OFFICES


ASSISTANT ADMINISTRATOR FOR RESEARCH AND DEVELOPMENT
OFFICE OF RESEARCH PROGRAM MANAGEMENT
OFFICE OF EXPLORATORY RESEARCH
OFFICE OF THE PRINCIPAL SCIENCE ADVISOR
OPERATIONS OFFICE
TECHNICAL INFORMATION OFFICE
OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT
OFFICE OF MONITORING AND TECHNICAL SUPPORT
OFFICE OF ENVIRONMENTAL ENGINEERING AND TECHNOLOGY
OFFICE OF ENVIRONMENTAL PROCESSES AND EFFECTS RESEARCH
OFFICE OF HEALTH RESEARCH
CARCINOGEN ASSESSMENT GROUP
PROGRAM OPERATIONS STAFF
PROGRAM OPERATIONS STAFF
PROGRAM OPERATIONS STAFF
PROGRAM OPERATIONS STAFF
EXPOSURE ASSESSMENT GROUP
QUALITY ASSURANCE AND MONITORING SYSTEMS DIVISION
WASTE MANAGEMENT DIVISION
TOXICS AND PESTICIDES DIVISION
AIR, NOISE AND RADIATION DIVISION
REPRODUCTIVE EFFECTS ASSESSMENT GROUP
TECHNICAL SUPPORT DIVISION
ENERGY PROCESSES DIVISION
WATER AND LAND DIVISION
WATER AND TOXICS DIVISION
CHRONIC EFFECTS ASSESSMENT GROUP
INDUSTRIAL & EXTRACTIVE PROCESSES DIVISION
ENERGY AND AIR DIVISION

Office of Environmental Processes and Effects Research. Seven laboratories conduct research on environmental processes and ecological effects for the DAA for processes and effects. The major focus of the research is to (1) develop the scientific and technological methods and data necessary to understand, predict, and ultimately to manage the entry, movement, and fate of pollutants into the environment and the food chain, and (2) to identify and predict the effect the pollutants will have on organisms and ecosystems.

This research provides fundamental support for decisions about pollution control strategies. For instance, as technology-based controls are put in place and other control strategies are aimed at site-specific areas exhibiting severe ecological impacts, a thorough understanding of the movement (transport) and fate (persistence or transformation) of pollutants is essential to assure that ambient control strategies are scientifically, technologically, environmentally, and economically attainable. The research program also assures that control technology resources are balanced between the benefits they produce and the costs they incur.

Office of Environmental Engineering and Technology. Research into devices and processes that control pollution is conducted at three laboratories which report to the DAA for environmental engineering and technology. The program conducts four major types of activities: (1) assessing pollution from industrial and municipal processes; (2) generating technical information on the cost and performance of control measures; (3) characterizing the performance of generic pollution control technologies; and (4) fostering improved pollution control measures. The program is designed to improve the effectiveness of the Agency's regulatory programs, first, by assisting in the process that generates data and information about the characteristics and treatability of pollution from various sources, and second, by improving the concepts that form the basis for pollution control decisions. The most important contribution the environmental engineering and technology program will make is in building the information base for the areas in which our information is weakest—the generation of hazardous wastes, the cost and performance of hazardous waste disposal technologies, the emission of hazardous air pollutants, and the environmental characteristics of emerging manufacturing technologies, particularly synthetic fuels. To improve the concepts for EPA's decisions, the research program emphasizes a multi-media and multi-pollutant approach to industrial regulation.

The program also evaluates the cost and capabilities of current pollution control practices and seeks to foster improvements, through scientific innovation, in the commercial sector.

Office of Monitoring Systems and Quality Assurance. Research into monitoring, pollution detection systems, and quality assurance takes place in three laboratories that report to the DAA for monitoring and quality assurance. The research, development, and demonstration programs focus on providing cost-effective measurement methods and monitoring systems, and developing quality assurance procedures and protocols to assure the generation of accurate environmental monitoring data. Major activities include:

- developing, demonstrating, and standardizing techniques, equipment, and systems to measure environmental pollutants at sources in the ambient environment and in receptors;
- developing methods, systems, and materials for an Agency-wide monitoring and quality assurance program; this program quantitatively determines the confidence level of all monitoring data used by EPA;
- overseeing the Agency-wide mandatory quality assurance program to assure the accuracy of environmental monitoring data; and
- providing monitoring support for solving immediate problems faced by EPA's regulatory regional offices.

Office of Health and Environmental Assessment. This special-purpose office conducts research concerning the evaluations of potential health hazards and the magnitude of the hazard associated with populations potentially exposed to environmental contaminants. The data from the research are essential for regulators to reach risk-benefit decisions about the desirability of specific regulatory approaches. As a decision tool, exposure and health risk assessments integrate and interpret available scientific data regarding the toxicity of substances and potential exposure in such as way as to present health impact conclusions, recommendations and/or criteria.

Eight of the Agency's major legislative mandates require some level of health and risk assessment. Typically, these assessments form the primary scientific basis for estimating health impacts for setting EPA's program priorities, defining regulatory approaches, analyzing policy initiatives, and supporting enforcement actions. Since May, 1976, ORD has provided a limited health risk assessment capability to EPA decision makers. The initial capability of risk analysis for carcinogenicity has been expanded to include a mutagenic risk analysis capability; in the near future we plan to establish procedures for evaluations of the toxicity risks to other reproductive systems.

Office of Exploratory Research. Established to improve ORD's overall capability to perform long-range research and analysis of emerging problems, this office has two major functions: (1) managing the competitive research grants process and the research centers support program, and (2) performing strategic analyses of environmental trends and conducting special studies on the impacts of emerging technologies. The activities of this office are described more fully in Chapter 1.

How Research Outlook 1981 is Organized

Each chapter of this year's Research Outlook addresses a specific area of environmental concern, corresponding to a particular segment of the Agency's regulatory program. Chapters summarize the research that will be conducted in the relevant scientific/technical disciplines to produce a coherent set of data for environmental policy formulation. The detailed research plans that form the basis of each of these chapters have been formulated by the thirteen research planning committees.

Typically, a chapter begins with a description of the specific environmental problem of concern to the Agency, e.g., the potential threat to man and his environment posed by the use of chemical pesticides. Following that general introduction is a presentation of the research expected to be produced in the coming five years. We have attempted to place our research plans in their regulatory contexts, identifying for the reader the critical data gaps to be filled in the next several years. The narrative portion of the chapter closes with a discussion of environmental, technological, and in some cases sociological and economic trends which may affect the direction of our longer-term research. These future trend projections, compiled from a variety of mathematical models and other data sources, are included to give a sense of the types of problems our research program must anticipate in order to be useful for longer-range policy formulation. Each chapter concludes with a listing of key research products planned for the 1981-85 period and the dates when outputs will be available.

However, these research plans are necessarily subject to change and are influenced dramatically by our annual process to plan budgets and allocate resources. Appendix A identifies expected resources for 1981-85 and indicates, in general terms, the programs' sensitivity to fluctuations in funding. For each research area, we have attempted to predict which aspects of the program would shrink or grow in response to budget increases or decreases over the next five years.

A Guide to the Chapters

Chapter 1: Environmental Research Planning and Management—describes managerial improvements introduced in the past year; reviews the development and current operation of the research committee system; and discusses our stewardship of the Agency's mandatory quality assurance policy.

Chapter 2: Energy and Environment—discusses research on the effects to human health and environment from domestic energy production; research on methods to control pollution; and research to study acid precipitation and synfuels development.

Chapter 3: Hazardous Air Pollutants—the first of four chapters that describe air pollution research, primarily focuses on airborne carcinogens and selected toxic air pollutants controlled under the hazardous air pollutants provision of the Clean Air Act.

Chapter 4: Gases and Particles—specifically addresses three airborne pollutants of concern to the Agency—particles, sulfur dioxide, and lead. Since the primary source of these pollutants is energy generation, however, control technology research is discussed in Chapter 2, Energy and Environment.

Chapter 5: Oxidants—describes research on atmospheric reactions leading to oxidant production, involving ozone, nitrogen oxides, and volatile organic compounds. Discussions include work on health and environmental effects, monitoring, modeling, and control techniques.

Chapter 6: Mobile Sources—focuses on exhaust products from automobiles and trucks, particularly those generated by diesel engines. Also included is research on the effects of carbon monoxide.

Chapter 7: Non-ionizing Radiation—describes research to determine whether typical human exposures to electromagnetic radiation sources such as radio frequencies, X-rays, and microwave ovens produce adverse health effects.

Chapter 8: Pesticides—covers research conducted in support of the pesticides registration and classification responsibilities authorized by the Federal Insecticide, Fungicide, and Rodenticide Act.

Chapter 9: Toxic Chemical Testing and Assessment—describes research on test development, health and environmental effects and monitoring as guided by implementation of the Toxic Substances Control Act.

Chapter 10: Solid Waste—covers research associated with the Agency's responsibilities under the Resource Conservation and Recovery Act and recently enacted "Superfund" legislation.

Chapter 11: Drinking Water—describes research underway and planned to strengthen the scientific and technical foundation of the National Drinking Water Regulations and the protection of groundwater supplies.

Chapter 12: Water Quality—the first of three chapters addressing water quality research, describes ambient water quality management programs, including support for water quality criteria and standards, non-point source pollution control, and ocean dumping.

Chapter 13: Industrial Wastewater—focuses on research into wastewater problems of conventional manufacturing industries and specific energy industries relating to electric power generation, coal mining and preparation, oil shale mining, oil and gas production, and uranium mining. (Wastewaters from the production of synfuels and gasohol, coal conversion, and oil shale retorting are discussed in Chapter 2, Energy and Environment.)

Chapter 14: Municipal Wastewater and Spill Prevention—describes research designed to: (1) provide the technological advances and technical support needed by the Agency's construction, enforcement, and area-wide planning programs, and (2) evaluate and improve our ability to control, clean up, and recover spills of hazardous polluting substances.

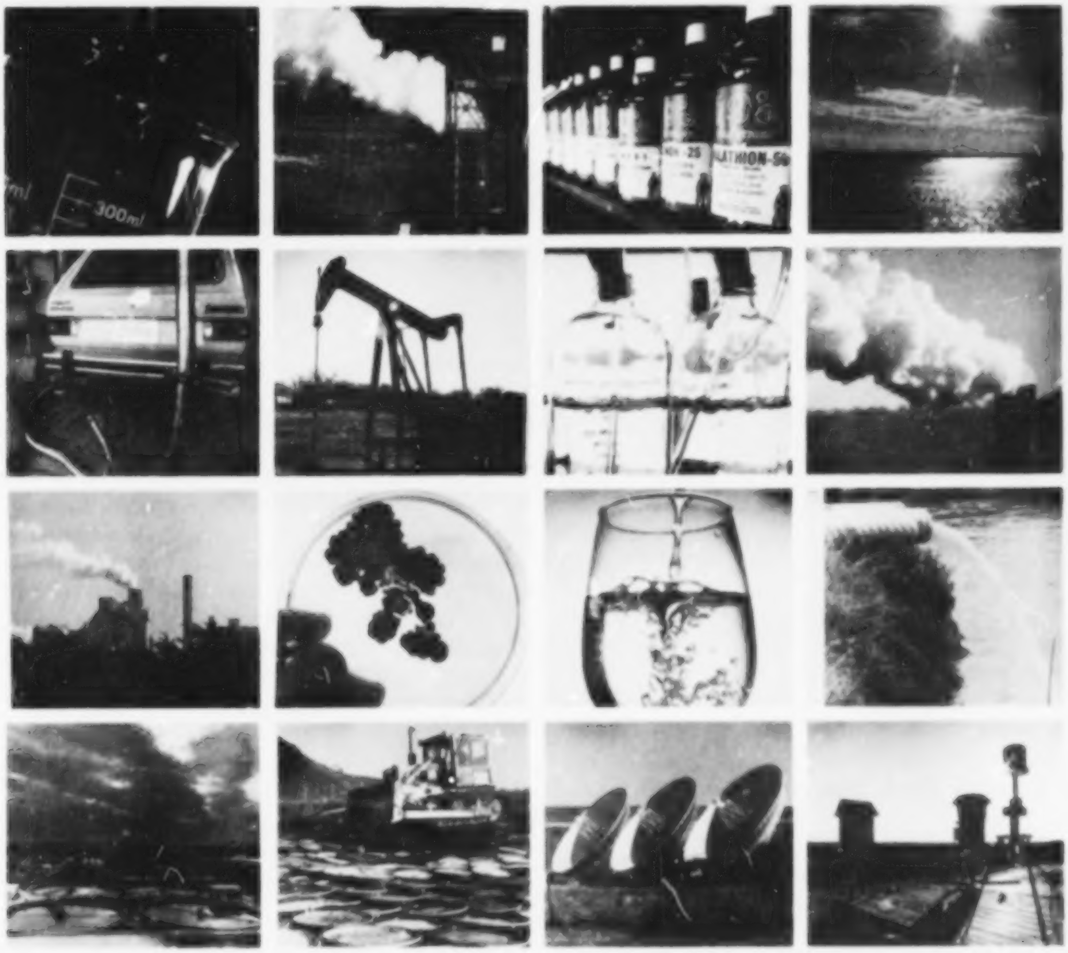
Research Priorities for the Coming Five Years

At present, EPA's Office of Research and Development is supporting close to 300 million dollars of research projects, scientific and managerial personnel, and a similar amount of laboratory facilities and scientific equipment. Our task is complex, demanding, and often contradictory. On the one hand, we must maintain a stable organizational climate that sustains first-rate research—frequently a time- and resource-intensive endeavor. On the other hand, we must be maximally flexible and responsive to rapidly changing societal concerns and shifting legislative and executive branch directives.

As we view the next five years, the research program will focus on:

- developing and implementing an integrated toxics strategy that will allow us to distinguish the key contributors and major entry points, transport routes, and effects of toxics in the environment, and thereby provide the basis for cost-effective controls to protect public health and the environment;
- rapidly providing the technical support and guidance necessary to implement the Superfund legislation, and instituting research to develop sound methods for assuring that cost-effective remedial actions are taken to minimize health and environmental damage from previously disposed hazardous wastes;
- providing the scientific underpinnings to address previously neglected, but now rapidly emerging, environmental problems such as groundwater contamination;
- improving our monitoring research, measurement methods, and quality assurance capabilities for priority toxic chemicals so that our data are credible and reliable;
- developing the methods and criteria to enable the Agency to design and operate more cost-efficient data collection and monitoring systems;
- examining new or improved approaches to environmental management, such as integrated waste management strategies;
- strengthening our capability to predict the transport, fate, and environmental effects of pollutants to permit the design of more cost-effective pollutant control management programs;
- developing sound guidance on the environmental performance of emerging industrial processes, such as synthetic fuels;
- enhancing the Agency's health hazard and risk assessment capability by: updating cancer risk assessment guidelines; finalizing mutagenicity and exposure assessment guidelines; providing guidance for describing multi-media exposures to complex mixtures; providing guidance for defining other health endpoints including reproductive and other chronic effects; and, in general, overseeing Agency-wide assessment activities; and
- developing and applying methods for assessing risks to public health by estimating the health effects of levels of pollutants found in the environment.

ENVIRONMENTAL RESEARCH PLANNING AND MANAGEMENT



During 1980, EPA further improved the planning and management of its research for support to regulatory decision making. The improvements include the refinement of a research committee system, the creation of a new office devoted to long-range research, the development of a peer review policy, a restructuring of technical information development and dissemination, and the development of an Agency-wide quality assurance program. These innovations, which essentially complete the restructuring of the Office of Research and Development, were initially set in motion by the introduction of a pilot research committee system in 1977.

The Research Committee System

The research committee system is an outgrowth of a pilot project which was designed to enhance the responsiveness and accountability of research conducted in, initially, five selected program areas. As a result of positive Agency-wide reactions to the project, the number of committees was subsequently expanded to thirteen, corresponding to regulatory program lines and thus encompassing the entire ORD environmental research program. EPA has now institutionalized this joint research planning system in which the committees

THE RESEARCH COMMITTEES

Energy

Gases and Particles

Oxidants

Hazardous Air Pollutants

Mobile Sources

Nonionizing Radiation

Solid Waste

Pesticides

Toxics Chemical Testing and Assessment

Drinking Water

Water Quality

Industrial Wastewater

Municipal Wastewater and Spill Prevention

regularly propose, plan, and oversee research performed by ORD. Each committee is composed of research staff members and representatives from the regulatory program offices, regional offices, the office of enforcement, the office of planning and management, and the office of environmental review. The committees' primary responsibility is to develop multi-year research strategies which reflect the members' view of the direction in which research should proceed to ensure the timely delivery of data to support future regulation development. Chapters 2 through 14 of this Research Outlook correspond directly to the thirteen research committees and have been derived, in large measure, from the strategies.

The major responsibilities of the research committees are to:

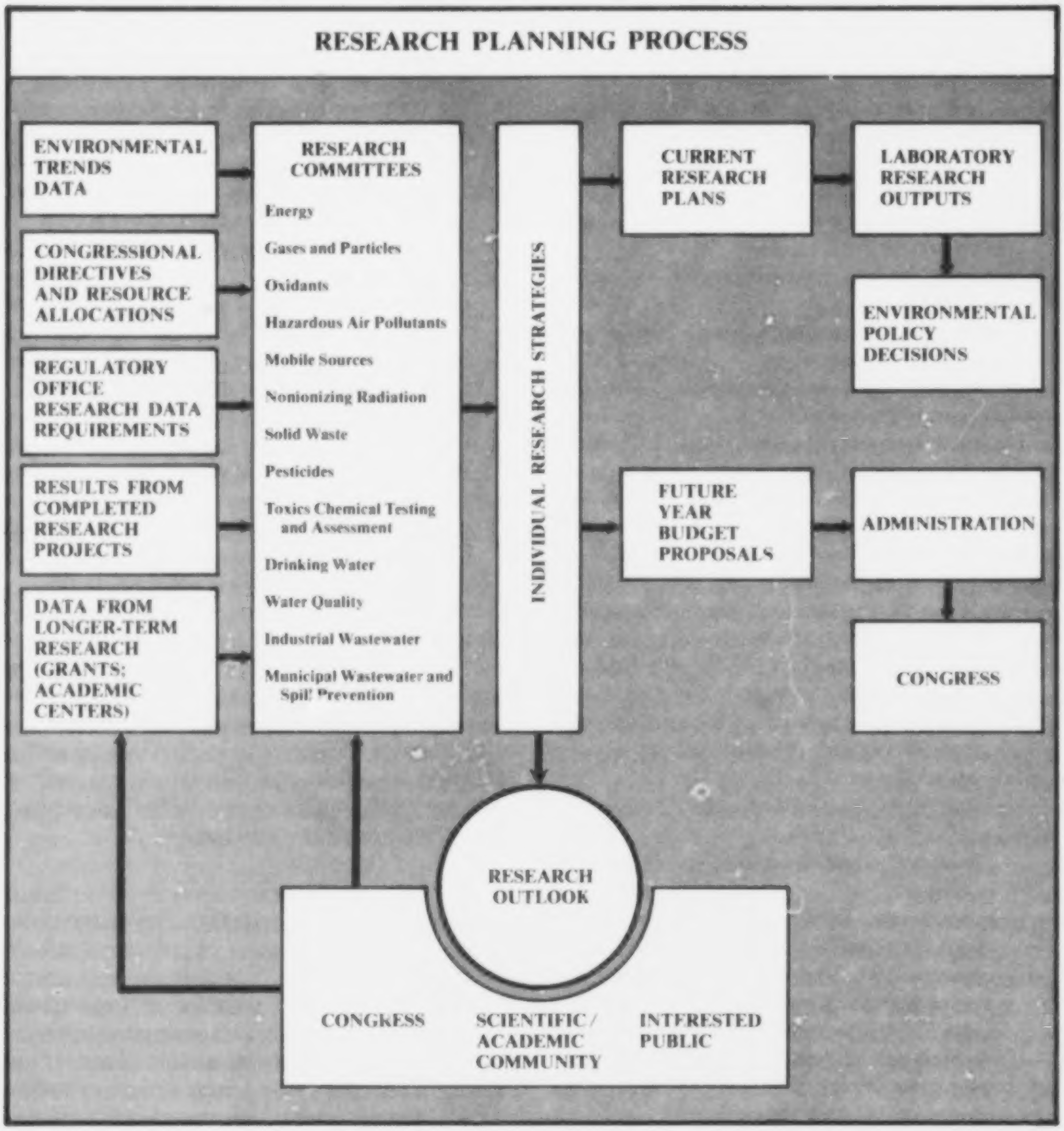
- identify and rank order research needed to support the operational requirements of the Agency;
- review the upcoming year's research plans and proposed laboratory outputs and formulate appropriate recommendations to improve them;
- actively participate in the development of budget year plans, including review and ranking of zero-base budget proposals;
- review the interim results of research underway or final results of recently completed research to assure responsiveness to Agency needs; and
- develop multi-year research strategies to serve as the primary planning documents in subsequent years. The strategies, which will bear the signatures of both the Assistant Administrator for Research and Development and the appropriate regulatory program Assistant Administrator, are to be updated annually.

Budget Restructuring. The "final step" in the institutionalization of the research committee system took place this past year with the realignment of ORD's budget categories to correspond to research committee subject areas. In past years, committee recommendations with fiscal implications were translated back into a budget structure which pre-dated the committee system. This cumbersome process made it difficult to track the implementation of committee suggestions and impeded the ability of research managers to make mid-stream program corrections in response to shifting regulatory requirements. Now, as the budget and accounting categories parallel committee lines, committee members can be directly involved in the formulation of ORD proposals and the review of research in progress. Each committee is thus able to see clearly how much is being spent on a particular topic of research, both in terms of dollars and personnel, and can help to determine the relative priority of specific areas of inquiry within the total program.

New Approaches to Funding Long-Term Research

The Office of Exploratory Research (OER) is a new organization within ORD. With its creation, EPA has added a dimension of stability and continuity to its long-term research program which did not previously exist. Housed in this new office are a competitive research grants and research centers support program and a strategic analysis and special studies program. These programs, in combination with certain intramural research efforts with long-term horizons, will improve ORD's ability to anticipate future problems that may jeopardize environmental quality; the programs will also provide information useful in formulating future policies.

Research Grants and Centers. Slightly over 100 grant awards have been made this past year; many of these grants address longer-term research issues. The total funding level of this program is $17 million. Each award was made pursuant to a rigorous competitive process instituted this year. In the past, grants were awarded by each laboratory, usually on the basis of


RESEARCH PLANNING PROCESS
ENVIRONMENTAL TRENDS DATA
CONGRESSIONAL DIRECTIVES AND RESOURCE ALLOCATIONS
REGULATORY OFFICE RESEARCH DATA REQUIREMENTS
RESULTS FROM COMPLETED RESEARCH PROJECTS
DATA FROM LONGER-TERM RESEARCH (GRANTS; ACADEMIC CENTERS)
RESEARCH COMMITTEES
Energy
Gases and Particles
Oxidants
Hazardous Air Pollutants
Mobile Sources
Nonionizing Radiation
Solid Waste
Pesticides
Toxics Chemical Testing and Assessment
Drinking Water
Water Quality
Industrial Wastewater
Municipal Wastewater and Spill Prevention
INDIVIDUAL RESEARCH STRATEGIES
CURRENT RESEARCH PLANS
LABORATORY RESEARCH OUTPUTS
ENVIRONMENTAL POLICY DECISIONS
FUTURE YEAR BUDGET PROPOSALS
ADMINISTRATION
CONGRESS
RESEARCH OUTLOOK
CONGRESS
SCIENTIFIC / ACADEMIC COMMUNITY
INTERESTED PUBLIC

in-house, EPA technical review only. In contrast, the new centralized grants process began with the issuance of a proposal solicitation brochure describing research areas of interest to EPA, followed by an extensive review of over 650 applications by five panels of experts (involving 180 qualified scientists from outside EPA). Each proposal was evaluated on the basis of the quality of the research described in it, the qualifications of the investigators, the appropriateness of the budget request, the level of support provided by the parent institution, and relevance of the proposed research to the mission of EPA.

After 3 award cycles in FY 1980, the following statistics are noteworthy:

- 72% of the awards have been made to qualified scientists who had not previously served EPA;
- about 17% of the original requests were funded, or roughly 1 out of 6;

- the average grant award was for $80,000 per year, funded for 2 years of a projected 3-year grant period; and
- of the five areas in which awards were made, the amount spent in each area is:
  —environmental biology: $3.5 million
  —health effects: $7.4 million
  —environmental chemistry and physics (air): $1.8 million
  —environmental chemistry and physics (water): $1.3 million
  —environmental engineering and control technology: $3.0 million

A publication which includes summaries of each award is currently available.

The research centers program is designed to provide long-term support for EPA's mission-oriented research programs, and to a lesser extent, to provide technical support on a short-term basis when necessary. The centers are affiliated with selected universities and specialize in areas of continuing concern to the Agency. Each center is selected on a competitive basis, and is funded at a level of $0.5 million per year for a planned five-year period. Center activities are conducted under cooperative agreements and overall guidance is provided by a policy board made up of appropriate EPA laboratory and headquarters staff and the center director.

We have now established seven "centers of excellence":

—advanced control technology: University of Illinois
—groundwater: University of Oklahoma, Oklahoma State and Rice University, in consortium
—epidemiology—University of Pittsburgh
—marine sciences: University of Rhode Island
—industrial waste elimination: Illinois Institute of Technology and Notre Dame, in consortium
—intermedia transport: UCLA
—ecosystems: Cornell University

The first four awards were made in FY 1979, the latter three in FY 1980. In FY 1981 we plan to select a hazardous waste disposal center to investigate the problems associated with disposal sites and to generate longer-range solutions to the problems.

Environmental Trend Projection. The Office of Strategic Assessment and Special Studies is the part of OER concerned with providing an improved understanding of likely futures and their environmental implications. The office is using a variety of approaches to identify and assess potential future environmental problems, including:

- Environmental Outlook—Using a number of formal and informal models and analytical methods, the staff is developing the ability to provide both qualitative and quantitative information about future environmental trends such as the impacts of population shifts and economic growth. The Office will publish an Environmental Outlook report each year, summarizing these data;
- special studies—studies to expand data bases in potentially significant future problem areas, e.g., the development of a particular resource or technology;
- innovative research—providing research opportunities for outstanding EPA scientists to pursue their personal innovative environmental research ideas; and
- mini-assessments—small-scale problem identification and definition studies, designed to provide enough information to make a preliminary determination of whether further study of a concern or potential problem is warranted.

The sections on emerging and future trends contained in each chapter of this Research Outlook were provided by the Office of Strategic Assessment and Special Studies to the research committees for their consideration in developing multi-year strategies. In future years, we expect to strengthen the relationship between this office and the committees, both to enhance ORD's predictive capabilities and anticipation of future regulatory program needs.

Improving Scientific Quality Through Peer Review

As of March 1, 1980, the Office of Research and Development implemented comprehensive and rigorous peer review procedures across all its organizational elements; all ORD laboratories, as well as Deputy Assistant Administrators, have developed peer review plans for all phases of research and development. A range of peer review procedures will ensure that our research meets the highest standards of scientific quality and credibility. These procedures include:

- the review of all research results for publication in scientific and technical journals. Research results not published in the refereed professional literature are peer reviewed in accordance with ORD's technical information policy;
- peer review of laboratory intramural and extramural research projects by approved non-EPA experts;

- inclusion of non-EPA scientists in laboratory-level, DAA-level, and AA-level program reviews;
- extensive review of grant proposals and research results by academic and other recognized experts;
- peer selection of candidates for the Innovative Research Program, a project intended to encourage the technical and scientific development of EPA scientists, and for the new EPA Science Achievement Awards, that recognize outstanding contributions of EPA scientists;
- extensive use of the Agency's Science Advisory Board in reviewing health and environmental criteria documents on which Agency regulations are based;
- Agency-wide standards of review for human health and environmental exposure studies; and
- extensive use of consulting experts to review all health and risk assessment documents.

Restructuring Technical Information

During the past year, the entire structure of ORD's technical communication efforts has been changed to streamline information flows, assure the accessibility of our research products and make the best use of our personnel and financial resources. The Technical Information Policy and Guide became formal ORD policy in March, 1980 after more than a year of analysis, review, and development of a consensus involving every major ORD office and laboratory. This new policy applies to all of the nearly 2,000 technical information products generated by ORD research each year. The process of implementing the new policy has progressed well, with all its major provisions in effect at this writing.

The major changes instituted by the new policy are:

- project reports are no longer printed by EPA. All are available from the National Technical Information Service (NTIS);
- all project reports are now summarized in a monograph containing the key findings of the subject report. This monograph is printed and distributed by ORD;
- heavy emphasis is placed upon documenting EPA research through publication in the peer-reviewed literature, rather than by government printed report;
- reports produced for the EPA regulatory offices are centrally filed for documentation and access;
- a technical information plan is produced annually by each ORD organizational unit. This plan identifies specific products to be produced by ORD research according to a specified schedule, and is distributed to the appropriate research committee(s) as a confirmation of planned research output; and
- major emphasis is placed upon producing information synthesis and summary documents aimed at major regulatory and policy-level audiences.

Agency-wide Quality Assurance

ORD is responsible for determining Agency-wide quality assurance (QA) policy that applies to environmental measurements for research as well as to measurements made by program and regional offices. Through FY 1980, the emphasis of the QA program was on publishing the policies and procedures to guide other EPA offices in establishing appropriate and comparable QA activities.

The emphasis is now on developing the specific, technical criteria to incorporate the appropriate level of quality control (QC) into all environmental measurements made by or for EPA. In particular, the program has the following goals:

- development of standard QC protocols to be incorporated, as an integral part, into EPA's standard analytical methods;
- specification of minimum data quality acceptance criteria to be applied to all data produced for EPA use;
- inclusion in all environmental data bases used by EPA of a data quality indicator that reflects the precision and accuracy of the method and the laboratory;
- implementation of a QA audit program that guarantees that all organizations producing data for EPA are inspected at least quarterly; and
- utilization of the ongoing laboratory automation program to develop an automated QA/QC reporting system that assesses the numbers and types of control problems and refines the applicable laboratory acceptance criteria.

Along with these specific objectives, we will provide the necessary training and technical support to EPA's programs and regional offices so that they may begin a secondary program of audits of systems and performance of contractors, states, permittees, and others.

ENERGY AND ENVIRONMENT

America is making progress in minimizing our dependence on imported oil. During the first five months of 1980, gasoline consumption decreased 8.1 percent—compared with the same period the previous year—and crude oil imports decreased to 7.8 million barrels per day—the lowest level in four years. Petroleum stockpiles nationwide are at capacity levels due to a very real, conscientious effort to conserve electricity, home heating fuel, and gasoline.

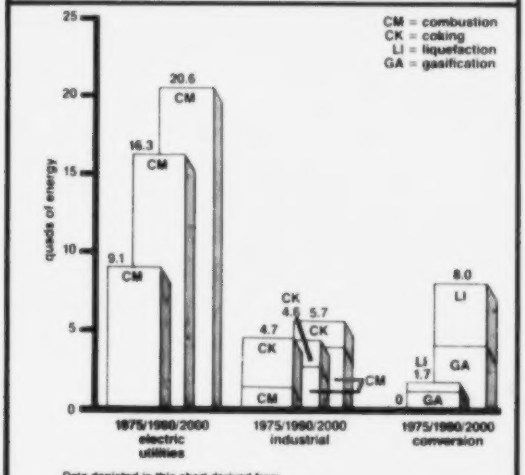
Of even greater significance for reducing our reliance on oil imports, however, is the Energy Security Act, enacted in June of 1980. This bill will promote conservation, increase production of coal and oil, help harness the power of the sun, wind, and rivers, and, most importantly, spawn a major synthetic fuel industry based on coal, oil shale, and biomass. In addition, it will support environmental research on two potentially serious combustion-related problems—acid precipitation and elevated global carbon dioxide.

To achieve the necessary growth in domestic energy resource development that will meet the future production goals called for in the Act, a substantial increase in extraction, processing, transport, and use of domestic fossil fuels must take place. EPA has recently projected our nation's energy future using the Strategic Environmental Assessment System (SEAS) model, an EPA-sponsored study of synfuel production, and an assumption that the rate of growth of overall domestic energy use will be much slower over the next two decades. These projections suggest that the nation's economic growth can be maintained by energy from coal, oil shale, and uranium despite the leveling off of supplies of domestic petroleum and natural gas and without increasing oil imports. For example, the amount of coal mined in this country is expected to increase from the current 700 million tons annually to 1.1 billion tons in 1990 to 1.6 billion tons in 2000. The production of synthetic liquid fuel and gas from coal is expected to consume approximately 80 million tons of the 1.1 billion ton 1990 estimate and 350 million tons of the projected 2000 total. We can also expect that the 1980s will see the oil shale industry emerge as a significant supplier of fuel, producing up to 300,000 barrels of shale oil per day by 1990 and 2.2 million barrels per day by 2000.

Such projections indicate a trend away from traditional and less environmentally damaging energy sources such as onshore oil and gas, toward potentially more damaging fossil fuel sources such as coal (particularly from western surface mines), oil or gas from the Outer Continental Shelf, and western oil shale.

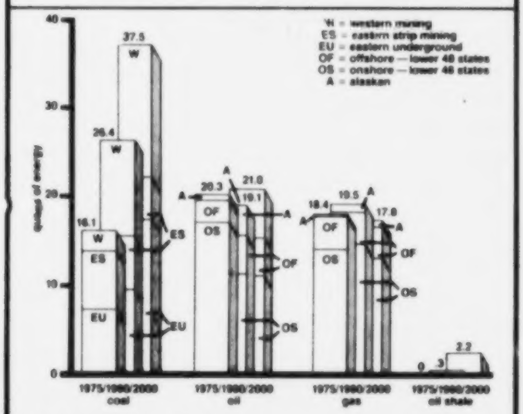
These major shifts toward the increased use of less clean fuels can pose a significant threat to human health and the environment as potential adverse impacts are likely to result from the extraction,

COMPONENTS OF DOMESTIC COAL UTILIZATION



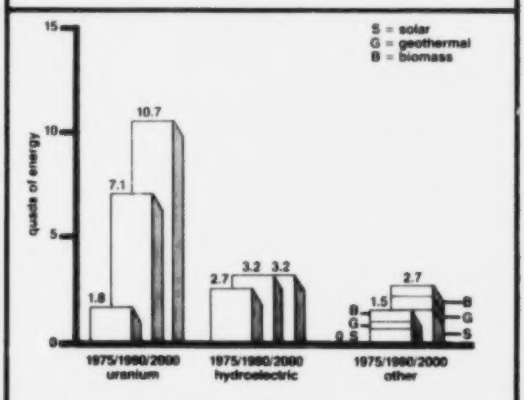
Data depicted in this chart derived from the "High Synthetic Fuels Scenario" developed for the Energy Processes Division of EPA's Office of Environmental Engineering and Technology.

DOMESTIC FOSSIL ENERGY RESOURCE REQUIREMENTS



Data depicted in this chart derived from the "High Synthetic Fuels Scenario" developed for the Energy Processes Division of EPA's Office of Environmental Engineering and Technology

U.S. NON-FOSSIL ENERGY RESOURCE REQUIREMENTS



Data depicted in this chart derived from the "High Synthetic Fuels Scenario" developed for the Energy Processes Division of EPA's Office of Environmental Engineering and Technology.

processing, and utilization of each major fuel. For example, increases in coal and oil shale mining can create erosion and subsequent surface water siltation problems; ground water quantity and quality can be degraded. Processing coal and oil shale to make synthetic fuels may create toxic emissions causing adverse health and environmental impacts, and burning more coal to generate electricity is expected to produce more nitrogen oxides, sulfur oxides, particulate matter, and solid wastes. Nuclear energy is beset with environmental uncertainties, and solar energy, though now seen as relatively benign to human health and the environment, will nevertheless have to be monitored for possible hazards.

Many of the potentially adverse effects of replacement fuel use, however, can be controlled or avoided. Mined land can be reclaimed, particulate matter and oxides of nitrogen and sulfur can be scrubbed from flue gases, and acid precipitation and its effects can be reduced. Reducing the adverse effects and establishing and enforcing controls will increase the monetary costs of energy, but failure to control pollutants will degrade the quality of our environment and imperil the health of our population.

THE RESEARCH PROGRAM

EPA's Energy/Environment Research and Development Program sponsors research that provides information to develop a scientific rationale for policies that balance domestic energy production with human health and environmental quality at a reasonable cost. Research that provides a basis for conducting meaningful and scientifically defensible exposure and risk assessments is performed to ensure that risks and benefits of policies are considered fully. Research to advance the state of the art of control technology is undertaken to reduce cost and improve efficiency. This combined research program is of interest to a number of other research committees which participate in planning the research and in utilizing research results.

The health and environmental effects research program focuses on three major areas: the identification of energy-related pollutants in the environment; the mechanisms by which these pollutants move through the environment; and their resulting effects on humans, animals, and plants. The control technology program provides information on pollutant types and quantities released by energy supply activities and develops or stimulates development of cost-effective control options. The control technology research will also produce technical data and cost information upon which reasonable environmental standards can be based. Emphasis will be on data to support establishment and implementation of technology-based environmental guidelines that will minimize environmental damage from energy fuels and processes.

Those fuels and processes judged to have the greatest potential for near-term adverse effects will receive study priority. During the next five years, focus will be placed on those current and projected processes for direct coal combustion and synthetic fuels from coal and oil shale. According to 15-year projections, these fuel sources are expected to see more growth than any others. According to scientific analysis, coal- and oil-shale-based processes also have the potential for causing major environmental problems in all phases of their production and use.

Shared interests between the energy/environment research program and several research committees will center mainly on the atmospheric transport, transformation, and dispersion of energy-related pollutants.

HEALTH AND ENVIRONMENTAL EFFECTS RESEARCH

In addition to EPA, agencies participating in this research are the Department of Energy (DOE), the Department of Agriculture (USDA), the Department of the Interior (DOI), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the National Bureau of Standards (NBS), the National Institute of Occupational Safety and Health (NIOSH), the National Institute of Environmental Health Sciences (NIEHS), and the Tennessee Valley Authority (TVA). The Department of Defense has also expressed interest in initiating or collaborating in this research.

Health Effects

The goal of the health effects research is to identify and assess the risks to human health posed by exposure to non-nuclear, energy-related pollutants. While some of the impacts are direct and easily traceable to the responsible agent, others manifest themselves only after long periods of low-level exposure and are

AIR, WATER AND SOLID WASTE ENVIRONMENTAL LAWS IMPACTING FOSSIL ENERGY FACILITIES

	Relevant Authority	Impact
Clean Air Act Amendments of 1977	• Set New Source Performance Standards (NSPS) for energy industries (Section 111).	• NSPS set for fossil utility boilers; industrial boiler NSPS being developed; oil shale, coal gasification, and liquefaction in planning stage.
	• Set National Emission Standards for Hazardous Air Pollutants (NESHAP) for selected industries (Section 112).	• NESHAP requirements for synthetic fuels industry being evaluated at process plans become firm.
	• Implement Prevention of Significant Deterioration (PSD) Program (Section 160).	• PSD permits required for all New Sources (coal-fired boilers and synthetic fuels plants) to prevent increases in particulate and SO_2 levels in areas having good air quality.
	• Achieve Ambient Air Quality Standards (Section 109).	• Require utilization of appropriate control technology to reduce emissions to levels required to meet State Implementation Plan (SIP) goals.
	• Set Lowest Achievable Emission Rates (LAER) (Section 171).	• Require level of pollution control technology greater than that which would normally be required by SIP for plant siting in non-attainment areas.
Federal Water Pollution Control Act Amendments of 1977	• Set discharge limits based on best conventional technology for energy industries (Section 306).	• Effluent guidelines for steam-electric industry issued, industrial boilers must meet guidelines for specific industry; effluent guidelines being planned for oil shale and coal gasification and liquefaction facilities.
	• Set discharge limits based on best available technology for toxic pollutants (Section 307).	• For designated toxic pollutants best available control technology will be required, and will have greatest impact on the design of synfuel plants.
	• Issue and enforce discharge permits to achieve above limits and to meet water quality standards (Section 402).	• Permits for electric utility plants and other industries being issued based on effluent guidelines; permits for synthetic fuels plants will be issued on basis of best information available until guidelines are issued.
Safe Drinking Water Act of 1974	• Review projects for possible danger to underground drinking water supplies (Section 1424).	• All projects receiving federal assistance will be reviewed for processes impact on groundwater quality as it may impact drinking water.
Resource Conservation and Recovery Act of 1976	• Set criteria for defining hazardous waste (Section 3001).	• Proposed procedures for determining if wastes are hazardous have been issued.
	• Define acceptable disposal practices for hazardous wastes (Section 3008).	• Utility wastes and spent oil shale classified as "special" wastes; if hazardous, they must meet monitoring requirements but not disposal requirements; best economically attainable disposable technology will be defined.
	• Set guidelines for non-hazardous waste disposal (Section 4004).	• Disposal guidelines for non-hazardous utility waste will be completed in 1981, other energy wastes subject to state guidelines.

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SYNTHETIC FUEL PROCESSES

major environmental concerns technology status	sulfur compound emissions	particulate/trace element emissions	organic emissions	contamination of surface/groundwaters	worker exposure to toxic/carcinogens	subsidence/aquifer disruption	fuel product(s) toxicity	disposal of spent shale	aquifer contamination
Coal Gasification High BTU gas: Lurgi technology close to commercial. All major components proven, but integration and cleanup systems untried at commercial scale. Medium/Low BTU gas: Technology is commercial with over 100 operating plants. Commercial experience lacking on gas and water cleanup.	●	●	●	●	●	●			
Indirect Coal Liquefaction (Coal Gasified Then Catalytically Converted to Liquids) Methanol plants using any of five processes have been commercially used in U.S. and overseas. Additional step allowing high octane gasoline production from methanol close to commercialization, Fisher-Tropsch, is operating commercially in South Africa.	●	●	●	●	●	●			
Direct Coal Liquefaction (Hydrogenation of Coal in Coal-Liquid) Several processes pilot tested including Solvent Refined Coal-II, Exxon Donor Solvent, H-Coal and Synthoil Processes. Scale-up required to large pilot or demonstration plant scale before commercial plant construction late 1980's or early 1990's.	●	●	●	●			●		
Oil Shale Processing Several above-ground and in-situ retorting processes at pilot scale and near commercial: Union, Colony-Tosco, Occidental and Rio Blanco (in-situ) have all initiated projects for the production of oil from shale at or near commercial scale.	●	●	●	●	●			●	●

difficult to associate with the causative factor. Moreover, human exposure to complex mixtures further complicates our ability to relate specific health effects to specific causes. Research will develop and validate tools, techniques, and models that will accurately identify energy-related pollutants and their combinations that produce health hazards, and will then examine the manner in which a pollutant affects human health. Considerable experimentation will be required, however, to correlate biological test results with human monitoring data. Studies will be conducted under the auspices of either the staff from a single agency or an interagency team. Organizations currently participating in the energy/health programs include EPA, NIEHS, NIOSH, and selected national laboratories.

Air pollutants from fossil fuels combustion. Criteria pollutants—those for which health and environmental-based ambient standards have been set—are sulfur oxides, nitrogen oxides, suspended particulates, non-methane hydrocarbons, ozone, carbon monoxide, and lead. The combustion of fossil fuels generates all these pollutants in significant quantities. Although much is known about the health effects of these pollutants, more knowledge is constantly being gained, and, as the effects become more understood, emission or ambient standards are revised accordingly.

Non-criteria pollutants, on the other hand, are those for which ambient standards have not been set. This category of pollutants includes sulfuric acid, nitric acid, nitrates, metallic oxides, heavy metals, asbestos, cadmium, vinyl chloride, benzene, and other organic and inorganic species, all of which are known to have deleterious effects on human health. Over the next five years, the emphasis on health effects research will shift from criteria to non-criteria pollutants.

The health effects of the non-criteria pollutants range from slight to severe depending on the level of exposure, the pollutant, the susceptibility of the individual, and other environmental and physiological factors. Effects on the present generation may include alterations of physiological functions, adverse reproductive effects, and cancer. Effects on the unborn may include direct damage to a developing embryo. A possible effect on future generations may be transmitted genetic damage resulting in the expression of disease (e.g., malformations, dysfunctions, behavioral disorders, mental retardation, cancer).

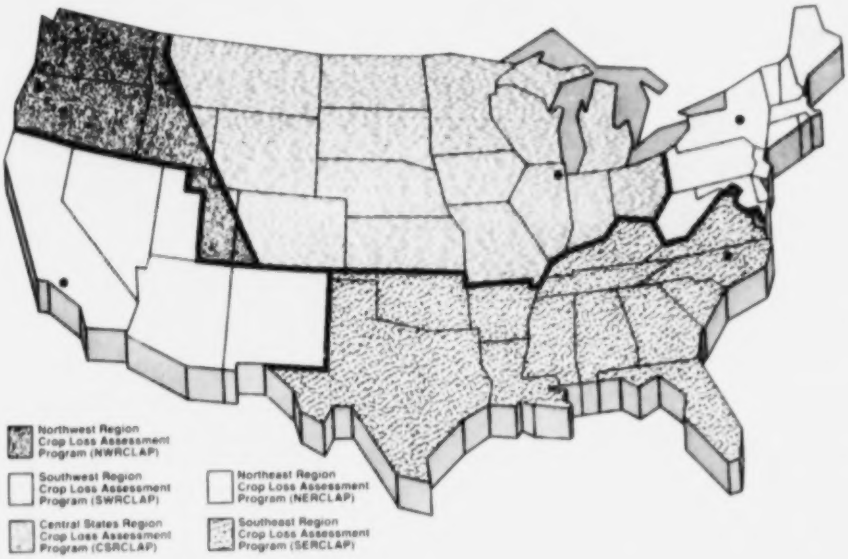
To preclude such adverse health effects, our current research includes a major effort to develop and validate short-term biological screening tests that quickly, accurately, and economically identify chemical substances as potentially hazardous. An important phase in the validation of these tests is an understanding of the significance of the resultant data; it is essential to link short-term test results with experimental data obtained from mammals and with human monitoring data.

This information will help develop methods to extrapolate results obtained with animal models to expected human effects. Adverse health effects caused by the less noxious pollutants will be determined through controlled clinical studies making use of volunteer subjects. Such studies also serve to identify high-risk groups, such as pregnant women, the elderly, and those with chronic respiratory disease. Human health effects of pollutants in high-population density areas (where air quality standards are sometimes exceeded) will be the subject of an epidemiological study. These clinical and epidemiological studies will supplement animal inhalation toxicology studies to provide the scientifically sound evidence for meaningful and legally defensible air quality standards.

Synthetic fuels and advanced fossil fuel combustion processes. Research to evaluate environmental effects of synthetic fuels was initiated during FY 1980 in response to President Carter's energy program and a congressional expression of the need for research to assess these new energy technologies.

Such technologies—advanced fossil fuel combustion and conversion processes—may generate a new group of polluting substances. These substances may be extremely hazardous to human health, and may affect it quite differently from the ways conventional fuel processes do. For example, coal burned in a fluidized bed generates an organic-coated fly ash that is different in geometry from ash produced by conventional coal combustion; the new ash also has a different form, size, and adsorptive character, and thus may have unforeseen health effects. Major synthetic fuel technologies—oil from shale, coal gasification, and direct and indirect coal liquefaction—also will generate by-products which, if inadequately controlled, can yield significant quantities of toxic substances. Various oil shale products are expected to be introduced into the commercial market in the foreseeable future; outputs from coal conversion technologies, both direct and indirect, are anticipated to increase. These expected trends thus require that the products of the synthetic fuels technologies be evaluated for impacts on human health.

EPA's synfuel assessment program, which centers on risk analysis of indirect coal liquefaction, direct coal liquefaction, and oil from shale, will develop the


NATIONAL CROP LOSS ASSESSMENT NETWORK

Northwest Region Crop Loss Assessment Program (NWRCLAP)
Southwest Region Crop Loss Assessment Program (SWRCLAP)
Central States Region Crop Loss Assessment Program (CSRCLAP)
Northeast Region Crop Loss Assessment Program (NERCLAP)
Southeast Region Crop Loss Assessment Program (SERCLAP)

information for evaluating those human health impacts. In the initial phases of the research the chemical compositions of the fuels will be investigated to determine if the fuels contain any materials of concern such as toxic components and/or compounds that may be mutagenic. The initial phases of research also will apply similar investigatory tests to the combustion by-products of synthetic fuels in order to evaluate the increased toxic potential including mutagenic effects of synthetic fuels as compared to petroleum fuels.

The latter phase of research includes the exposure assessment phase. In this phase, direct human exposure to the dangerous synthetic fuels components through air and water routes, and indirect exposures through the food chain will be assessed. Data generated by exposure assessment research will be used to evaluate potential adverse human health effects.

Animal experiments are being conducted to evaluate the toxic effects of these fuels. The experiments will test for inhalation toxicity and reproductive toxicity.

Environmental Effects

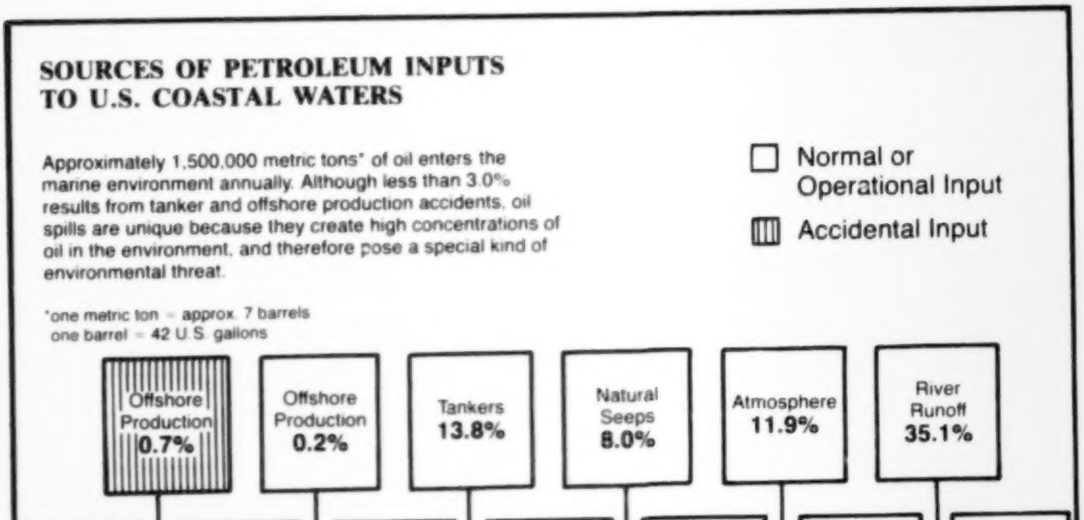
Fate and resiliency of aquatic ecosystems exposed to hazardous/toxic substances. Our environmental effects research will develop evaluation techniques to assess the long- and short-term impacts of petroleum on marine ecosystems. Effects of oil spills on aquatic populations and communities will be identified, and recovery rates of damaged ecosystems will be evaluated. Research will include studies of bioaccumulation of petroleum hydrocarbons in fish and shellfish and the impacts of petroleum spills on shorelines and beaches. Research in FY 1981 will establish techniques to evaluate resiliency of marine systems based on cause and effect relationships of spills and ecological damage. The research is in direct response to Section 311 of the Clean Water Act of 1977, which calls for evaluation techniques to determine the impacts from spills of petroleum and hazardous substances.

Pollutant deposition effects on ecosystems. This field-oriented research will provide technical information needed to protect forest, agricultural, aquatic, and recreational resources that may be affected by atmospheric pollutants from energy-related industries. The three major research areas are: (1) the determination of the economic impacts of gaseous air pollutants (SO_2, NO_2, and O_3) on crops; (2) the development of strategies for complying with prevention of significant deterioration (PSD) regulations; and (3) the evaluation of the impacts of acid deposition on aquatic and terrestrial ecosystems. The acid precipitation program is discussed later.

The crop impact research focuses on pollution interaction evaluations and the development of crop growth and yield models for use in economic assessments. The PSD strategies research will provide methods to evaluate air pollution impacts on fish, wildlife, and their habitats that are in Class I Air Quality Areas.

The atmospheric pollution effects research responds to Sections 108, 109, and 302(h) of the Clean Air Act, which pertain to developing scientific bases for establishing and revising secondary air quality standards; Section 111 of the Act, which concerns New Source Performance Standards (NSPS); and Part C, Sections 160-169, which concern the prevention of significant deterioration of air quality.

Offshore drilling for oil and gas. To meet the demands for oil and gas, the amount of offshore drilling is being increased. However, the discharges from offshore drilling activities may harm the marine environment. Past simulation studies have revealed that in high concentrations, certain pollutants from drilling fluids, drilling muds, and process water are hazardous to marine organisms. To complete the research in this area, we will produce state-of-the-art assessment documents which will be completed in late FY 1981.



SOURCES OF PETROLEUM INPUTS TO U.S. COASTAL WATERS

Approximately 1,500,000 metric tons* of oil enters the marine environment annually. Although less than 3.0% results from tanker and offshore production accidents, oil spills are unique because they create high concentrations of oil in the environment, and therefore pose a special kind of environmental threat.

*one metric ton = approx. 7 barrels
one barrel = 42 U.S. gallons

☐ Normal or Operational Input
▥ Accidental Input
Offshore Production 0.7%
Offshore Production 0.2%
Tankers 13.8%
Natural Seeps 8.0%
Atmosphere 11.9%
River Runoff 35.1%
Non-Tankers 1.3%
Tankers 2.0%
Urban Runoff 6.6%
Non-Refinery Industrial Waste 6.6%
Coastal Municipal Waste 6.6%
Coastal Refineries 2.0%
Non-Tankers 5.2%

Source: U.S. EPA 1979. Decision Series — A Small Oil Spill at West Falmouth. EPA-600/9-79-007.

Mine reclamation. As the extraction of coal, oil shale, and uranium continues to accelerate, cost-effective mining reclamation strategies are needed to mitigate pollution impacts on water quality, top soil, and land use. Because much of the expected mining will be in arid and semi-arid areas of the western United States, the research will identify: (1) practices to prevent and control wind and water erosion; (2) methods to improve the quality of water transported from mined areas to natural waterways; and (3) techniques for optimizing the use of reclaimed land.

The USDA, in concert with EPA, is conducting research to examine and develop management practices for environmentally sound reclamation strategies. This research includes development of new types of vegetation that will protect arid and semi-arid top soil from erosion; it also will attempt to improve revegetation of mined lands by irrigating with water from fluidized bed wastes and municipal wastewater sludge. In addition, the use of reclaimed land for the production of food crops is being studied. As an adjunct to this study, EPA and USDA are evaluating techniques that can make optimum use of precipitation that falls in arid regions.

An important part of the mine reclamation program is the development of management practices for reclaiming areas disturbed by uranium exploration and used as depositories for hazardous tailings from past uranium mining. Research will provide regulatory guidance for uranium mining, from exploration to the final disposal of tailings. This work will culminate with the publication of user-oriented manuals of practice which will be completed in FY 1982.

Synthetic fuels. EPA currently has two complementary research programs for synfuels, one for health and ecological aspects and one for environmental assessment and control technologies.

The health and ecological program investigates the possible impact of the synthetic fuel itself and its by-products upon human health and the environment. The environmental assessment and control technology program attempts to determine the kind and amounts of possible pollution from synfuel facilities and to develop, demonstrate, and evaluate methods to control such pollution.

EPA's laboratories plan risk assessments of synfuel products, by-products, emissions, effluents, solid waste, and other industry materials. Research will cover air, water, and solid waste as well as toxic substances. The Agency will examine all major synfuel categories including oil shale, direct liquefaction, gasification, and indirect liquefaction of coal.

Acid precipitation. The phenomenon of acid precipitation—both rain and snow—has been identified as one of the major environmental problems of the decade. Acid precipitation formed in the atmosphere as a result of the combustion of fossil fuels is known to affect lakes, streams, and wetlands adversely. Current research is investigating effects on forests, crops, materials, and drinking water. It is clear that the acidity of rainfall is increasing, and serious damage to susceptible lakes in certain areas of the country has been documented.

Fossil fuel power plants, industries, and motor vehicles are the main source of sulfur and nitrogen oxides—the major formative components of acid precipitation. But how these pollutants react in the atmosphere, the manners by which they are transported and deposited, and how they ultimately affect people and the environment are unanswered questions being addressed by EPA's research and development program. The acid rain research program also supports development of a control technology, the limestone injection/multistage burner, that may prove retrofittable and cost-effective for controlling production of pollutants at their source. This program complements flue gas desulfurization techniques and low-NO_X burner technologies being developed in other programs.

The Acid Precipitation Act of 1980, passed by Congress as Title VII of the Energy Security Act of 1980 (PL 96-194), was signed into law by the President on June 30, 1980. The purposes of Title VII are:

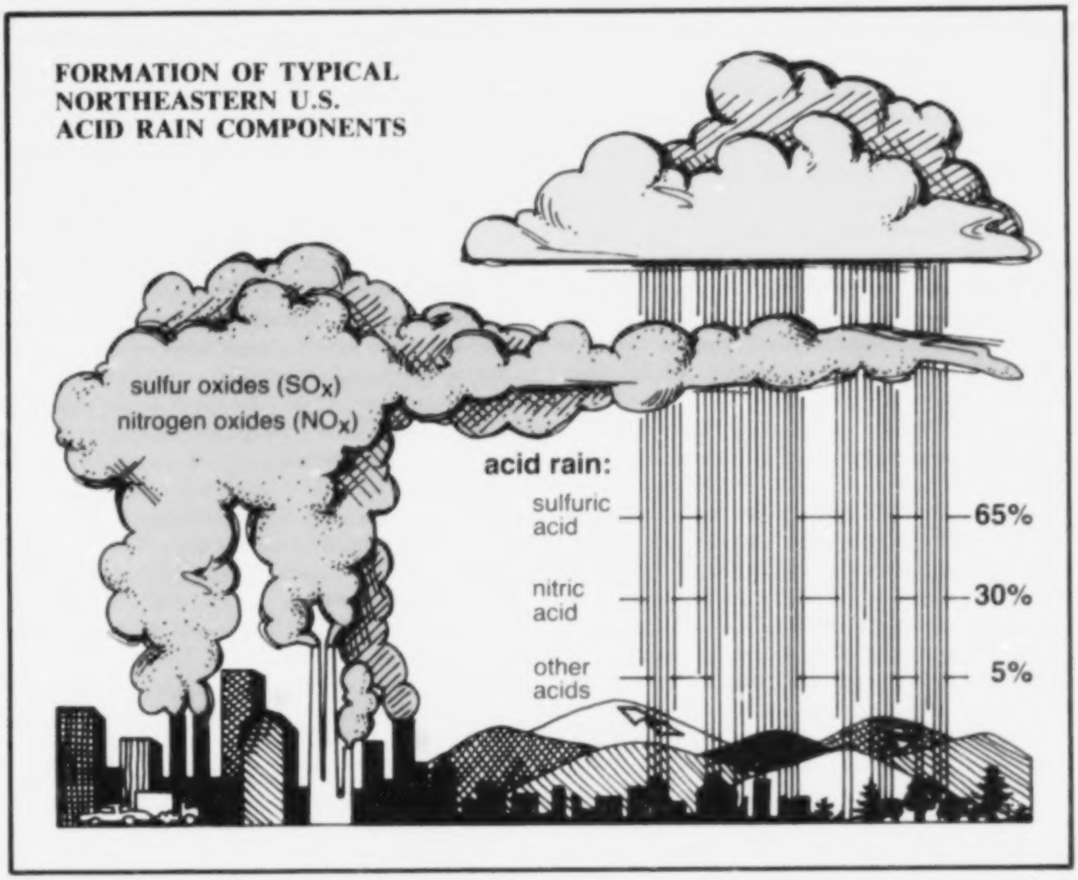
(1) To identify the causes and sources of acid precipitation;

(2) To evaluate the environmental, social, and economic effects of acid precipitation; and

(3) Results of the research program established by this subtitle and to the extent consistent with existing law, to take action to the extent necessary and practicable (a) to limit or eliminate the identified sources of acid precipitation, and (b) to remedy or otherwise ameliorate the harmful effects which may result from acid precipitation.

The Act calls for a comprehensive ten-year program and establishes an Interagency Task Force on Acid Precipitation, on which EPA serves as co-chairman, to plan and implement the national effort mandated. This Task Force was charged with developing a comprehensive plan for the program and presenting a draft of the plan to Congress within six months after the bill.

The draft National Acid Precipitation Assessment Plan, prepared by the Task Force to fulfill its



FORMATION OF TYPICAL NORTHEASTERN U.S. ACID RAIN COMPONENTS

responsibilities under the Acid Precipitation Act of 1980, includes provisions to deal with all the legislatively mandated elements. In addition, this plan includes general descriptions of the phenomena and possible effects of acid precipitation, and provides a basic rationale for the federal research program proposed. EPA has accepted "lead agency" roles in aquatic effects, control technology, and integration and policy analysis and is represented in all other areas of the program. EPA's research program for FY 1982 and beyond will be carefully structured to reflect needs and provide leadership for the federal program.

Task Force efforts in planning and implementing a National Acid Precipitation Assessment Program were built upon previous federal activities. Prior to the passage of the Acid Precipitation Act of 1980, a presidentially initiated effort to develop a coordinated federal program was well under way. The Acid Rain Coordinating Committee (ARCC), co-chaired by EPA and the Department of Agriculture, was established as a result of the President's Environmental Message of August 2, 1979. In October 1980, the ARCC became part of the statutory Interagency Task Force on Acid Precipitation formed in response to PL 96-294. The Task Force includes the original ARCC members plus additional representatives required by the new law.

The ARCC prepared a draft "Federal Acid Rain Assessment Plan" and in September 1980 sent it for review by a broad spectrum of individuals in academia, private industry, state and local government, and federal agencies. This draft plan (and the more than 100 critiques received by the ARCC) was used by the Task Force as a starting point in developing the current plan.

Although many aspects of the ARCC draft plan were utilized in the preparation of the current plan, extensive revisions and additions were included in response to the legislation, critiques of the ARCC draft, and guidance by Task Force members.

The 10-year plan is for vital research; vital because today, acid rain knowledge is insufficient to provide a thorough understanding of the nature of the problem. What is known, however, is that acid rain is a global problem that results in a key inequity: The populace of one state or country enjoys the economic and industrial benefits that are derived from energy production, while these in locales not benefitting must pay the price of the consequent pollution. As international boundaries are crossed, the resolution of such inequities grows more and more complex. (See also discussion of acid rain in Appendix C, Global Issues and International Cooperation.)

Acid rain research is presently being conducted by many government agencies and by private industry. Those directly involved include in addition to EPA: the Electric Power Research Institute, the Forest Service, the Fish and Wildlife Service, State Agricultural Experiment Stations, the Geological Survey, the National Science Foundation, the Department of Agriculture, the National Oceanic and Atmospheric Administration, the Department of Energy, the Tennessee Valley Authority, and many research institutions, universities, and industry groups.

Within EPA, two overall themes provide a framework for ongoing research and development. One theme is that EPA must communicate to Congress and to the public the effects of acid precipitation, with special attention paid to the ecologic and economic consequences of continued high levels. The second theme states that EPA must continue to generate additional information that can be used to develop air quality control strategies and options.

Currently, EPA is working together with many other agencies to gather and interpret the scientific information necessary to evaluate and assess the impacts of acid rain and to provide the data needed to establish a foundation for control technology decisions. These programs are designed to: (1) monitor the sources and deposition of acid-causing pollutants; (2) discover and model the means of transport and transformation in the atmosphere, including the chemical reactions that take place in the air; and (3) determine the environmental effects that are caused by acid rain on crops and forests, wildlife, aquatic organisms, property, and people.

President Carter also spelled out the need for public participation in the acid precipitation issue when he directed the Acid Rain Coordinating Committee to "actively solicit public involvement in its planning and reviews of the research results of the Committee's program . . ." The new Interagency Task Force formed under PL 96-294 will include four public members and will ensure that future research directions by EPA and other agencies will speak directly to the needs and best interests of the American people.

Research on acid precipitation and its effects in the United States must be built upon past data and efforts to study the problem both in North America and abroad. EPA research relevant to acid rain includes: programs to help discern how atmospheric sulfur products move long distances; technology development programs to devise means to control the sulfur at the source; investigations into the effects of acid rain on aquatic and terrestrial ecosystems and materials; and providing assistance in the establishment of networks for rainwater collection and analysis to monitor pollution deposition. Building on this work and on other already available data, some potential acid rain research directions in the effects area are:

- investigation of the causes of the widespread acidification of rain in the eastern United States over the past 20 years;
- exploration of the rate at which rainfall is becoming more acid and the rate at which the problem is becoming geographically more widespread;
- examination of the quantitative contributions of various acids, especially nitric acid, to the overall acidity of rainfall;
- investigation into the relative extent to which the acidity of rainfall in a region depends on local emissions of sulfur and nitrogen oxides versus emissions transported from distant sources;
- establish properties of soils and waters making them especially susceptible to acid precipitation (i.e., those soil properties important to plant growth);
- survey of the continent-wide extent and severity of acidification of aquatic and terrestrial ecosystems, including impacts on fisheries, crops, and forests;
- collection of baseline data so that the effects of continued acid precipitation may be monitored and measured;
- determination of the tolerance of aquatic organisms, forest and orchard trees, and agricultural crops to factors associated with acid precipitation;
- development of diagnostic tests for acid damage to plants and animals and man;

- continuation of whole ecosystems studies for further information on nutrient cycling chemical budgets;
- examination of synergistic effects of pH and heavy metals, disease, and other adverse factors;
- studies on the impact of acidic snowmelt on streams and lake biogeochemistry;
- analyses of economic damage to sensitive ecosystems and materials;
- long-term consequences to land fertility and productivity of chronic acid precipitation; and
- determine properties which will make certain systems particularly susceptible to acid precipitation damage.

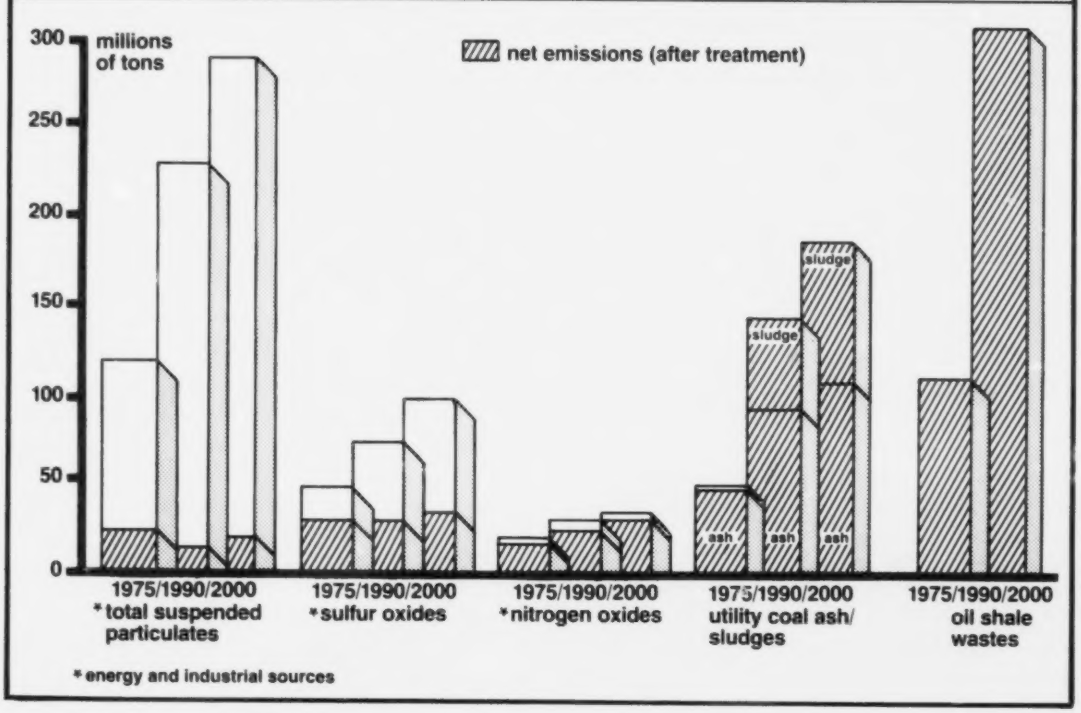
CONTROL TECHNOLOGY RESEARCH

As the nation shifts its energy emphasis to the increased use of coal and the development of a viable synthetic fuels industry, it is important that low-cost technologies and techniques are available that will allow such fundamental change without unacceptable environmental impacts. The goal of EPA's Control Technology Program, therefore, is to allow the nation's wealth of domestic energy supplies to be used in an environmentally prudent manner, without unreasonable cost penalties.

The program is divided into two major categories that correspond with the most important portions of the current and projected fuel cycle: fossil fuel combustion and synthetic fuel production and use.

Fossil fuel combustion. Despite the growth of a major coal-based synfuel industry, conventional combustion will continue to be the prime method for utilizing coal well into the 21st century. Furthermore, evolving energy policies are clearly emphasizing increased reliance on coal for electricity and steam generation. For example, the National Energy Act of 1978 prohibits any new oil or gas utility boilers and mandates that many utility and industrial power facilities convert from oil and gas to coal. Moreover,

GROWTH IN EMISSIONS/WASTES FROM STATIONARY SOURCES



President Carter proposed additional legislation to promote the retirement by 1990 of all existing oil-fired power plants. This national movement toward increased coal use underscores the need for developing economical and effective technologies to control the release of pollutants generated during coal combustion. The main pollutants are sulfur oxides, nitrogen oxides, particulates, and solid waste by-products from devices used to reduce sulfur emissions and fly ash. The primary objective of our research is to develop and demonstrate cost-effective control technology to limit the release of these pollutants, making future utility and industrial processes less environmentally damaging.

Sulfur Oxide. Sulfur oxides are precursors of the formation of sulfate particulates, which cause health problems and are implicated as contributors to acid precipitation. Projected coal combustion will increase the amount of sulfur oxide put into the atmosphere, thereby offsetting air quality gains that might have come about from the current sulfur oxide regulations, including the recently promulgated New Source Performance Standards for utility boilers. To control future sulfur oxide emissions, our research will study flue gas desulfurization (FGD) and lime and limestone scrubber systems.

Flue gas desulfurization is currently the only sulfur control technology that will be generally applicable to utilities and industries during the next ten years. Estimates are that by 1990, electric utilities will have invested between $10 and $20 billion to build and operate FGD units. Although some commercial FGD installations are now performing reliably and effectively in the United States and abroad, further research, development, and demonstration of the technology will produce improved operating efficiencies and costs. EPA and DOE are jointly pursuing FGD improvements.

Though lime and limestone scrubber systems are commercially available at present, they would benefit from additional research. We are currently attempting to raise the reliability and performance of the scrubbers, lower system costs and demonstrate environmentally acceptable sludge disposal practices. To meet these goals and to support EPA's regulatory and enforcement activities, ORD will work closely with utilities and industries to: (1) develop and evaluate low-cost dry scrubbing systems as an alternative to wet scrubbing; (2) demonstrate the ability of organic additives in limestone scrubbers to improve SO_2 removal and lower costs; and (3) define acceptable sulfur sludge disposal practices.

Another major part of our program will develop other, new, low-cost sulfur oxide control techniques. One promising technique is the simultaneous injection of coal and limestone into a low-NO_X burner. Preliminary data from initial tests of the technique indicate sulfur oxide and nitrogen oxide removal rates of between 50 and 70 percent may be achieved at a significant cost savings over conventional wet scrubbers for both new and existing boilers. Full development of this technique will take five years but will culminate in the demonstration of a limestone injection/multistage burner (LIMB) in boilers of modern utility design. The new technique offers potential low-cost simultaneous reductions of sulfur oxide and nitrogen oxide emissions from existing sources of the pollutant. It may be the most economical way to deal with acid precipitation problems that have been linked to existing coal-burning facilities.

Nitrogen Oxides. Recent research indicates that nitrogen oxides could be one of the most troublesome air pollutants of the 1980s. More than 20 million metric tons of NO_X are annually polluting our air as a result of the widespread combustion of fossil fuels in power plants, industrial boilers, and automobiles and trucks. If present trends continue, nitrogen oxide emissions could grow by 50 percent over the next 20 years, with the increases coming primarily from industrial sources.

Present levels of NO_X emissions already pose a significant threat to our health and environment. This threat is due not only to the widespread nature of combustion sources, but also to the unusual chemical properties of NO_X. Nitrogen oxides are precursors of photochemical oxidants such as ozone, the major component of urban smog. NO_X can also be converted into nitric acid, one of the two principal components of acid precipitation.

As the nation increasingly turns to coal as a bridge to cleaner sources of energy, we must recognize that, at the current levels of controls, coal-fired plants will continue to emit more nitrogen oxides than gas- and oil-fired plants. However, since natural environmental processes are not able to cope with even current NO_X emissions, possible emissions increases demand that we move rapidly to improve control technologies for all the major sources in the future. EPA has been involved in a major research and development effort to control NO_X emissions during the combustion process. Low-NO_X burners offer the potential to drastically lower NO_X emissions while simultaneously maintaining or improving fuel efficiency. This means that the cost of either a utility boiler or the electricity produced from it will not be significantly affected. Furthermore, a low-NO_x burner does not produce any residual product that must be disposed of after combustion (such as sludge from a sulfur scrubber).

Full-scale low-NO_x burner demonstrations on two industrial-sized boilers were initiated in 1980. A similar demonstration on a 300-MWe utility-scale boiler will begin in 1981.

Particulates. Fine particulates are a health hazard because they can by-pass the body's respiratory filters and penetrate directly into the lungs. They remain airborne for extended periods of time, obstruct light, and cause limited visibility or haze. Furthermore, toxic metals and hazardous compounds that tend to adsorb or condense on fine particles are often transported through the air by them. The particles may originate as primary emissions or may be transformed into secondary pollutants from gaseous emissions such as SO_2.

Technology for controlling the release of airborne particulates has remained relatively stagnant since the turn of the century. Now, however, with the press to raise collection efficiencies, lower the limit of particle size collected, and concurrently keep costs down, the technology will again advance. Our research will develop controls for particulates from sources with widespread national implications. Such sources include power utilities that will increase their current use of coal or that will switch from oil and gas to low-sulfur coal. We will also continue to support the reduction of particulate control cost impacts, with the major focus on low-sulfur coal combustion controls such as electrostatic precipitators and fabric filters. Attention will also be given to particle prechargers that offer the potential of reducing particulate control costs by 50%.

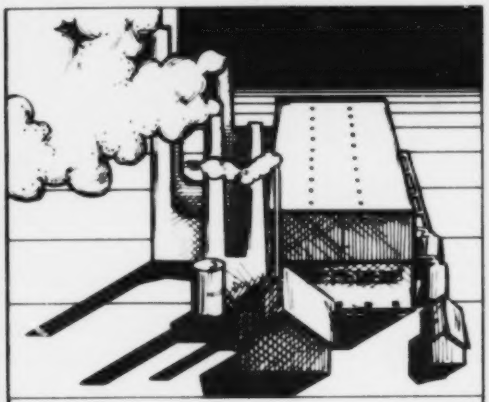
For energy and industrial sources, we will develop data on particle size distribution before and after use of the control device. This data will help EPA analyze appropriate control strategies associated with possible revision of the current Total Suspended Particulate Standards or for replacement of these standards with Inhalable (fine) Particulate Standards.

Another major activity will be the monitoring of commercial installations utilizing advanced baghouses and electrostatic precipitators. This work will help to support EPA's regulatory program aimed at defining New Source Performance Standards (NSPS) for utility and industrial boilers based on best available technology.

Synthetic fuels. EPA is accelerating its research to evaluate and develop pollution controls for synfuel processes. This acceleration is particularly important because effective environmental controls incorporated at the formative stages of a synfuel plant can facilitate the plant's permit and leasing process while assuring immediate environmental protection. The major synfuel processes nearing commercialization are direct and indirect coal liquefaction, coal gasification, and oil shale retorting. Pollutants from the forms of coal and oil shale used for synfuels generally differ from those associated with normal coal combustion. Synfuel processes result in fewer emissions of conventional air pollutants, such as sulfur oxide and nitrogen oxide, but have the potential for increased emissions of high molecular weight organics and other toxic materials.

Our research will accelerate efforts to evaluate control technology for the major process streams of first- and second-generation synfuel processes. Areas to be evaluated are the performance and cost of control technologies for the major coal liquefaction, gasification, and oil shale processes. Primary and secondary pollutants from these processes will be identified and quantities estimated; methods of pollution control will be identified and carefully evaluated. Air, water, and solid waste effluents will be studied from all process sources, including (1) the conversion process, (2) the environmental controls process, and (3) any ancillary processes such as oxygen production and steam generation. The research is being carefully coordinated within EPA so that results can assist air, water, and solid waste regulatory and enforcement offices to perform their regulatory and permit duties effectively. Major efforts are also being made to coordinate with the Department of Energy in order to ensure access to their synfuel facilities and to encourage continued joint environmental assessment research programs.

The major near-term outputs from the environmental assessments for synthetic fuels research will be a series of pollution control guidance documents for technical support for the major synfuel processes. The documents, to be published during the next two years, will provide environmental control guidance to synfuel developers and permitting authorities prior to promulgation of legally binding standards. Such documents are expected to expedite the permit process by describing best control practices and technologies currently available that will optimize the environmental protection achieved for each dollar invested in environmental control for air, water, and land protection.



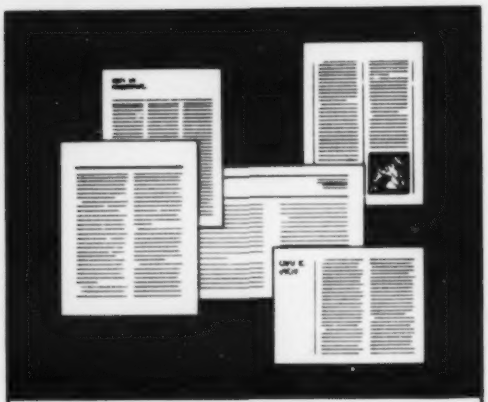
EPA ALTERNATE FUELS GROUP

STRATEGY

- provide clear pollution control requirements on a timely basis
- promote use of best available control technologies & practices by:
  - — publishing pollution control guidance documents
  - — issuing technology-based standards

MAJOR ACTIVITIES

- develop EPA synthetic fuel regulatory program
- produce pollution control guidance documents
- oversee creation of program to develop coordinated multimedia standards
- generate & update five-year research plan



SYNTHETIC FUELS POLLUTION CONTROL GUIDANCE DOCUMENTS

PURPOSE

- provide guidance for permit writer
- convince developers to install best controls
- establish reasonable controls
- provide information for public comment during 1981

APPROACH

1. select process & process configuration
2. define streams of concern
3. define pollutants of concern
4. define costs & capabilities of control
5. recommend performance

ENERGY AND ENVIRONMENT RESEARCH PLAN

Energy/Health

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Human Studies with Primary and Secondary Pollutants from Energy Systems	Conduct analytic studies of populations exposed to contaminated drinking water	▲				
	Conduct analytic studies of populations exposed to elevated levels of SO_2 and particulates	▲				
	Evaluate physiological reactions of normal and susceptible human populations to specific particulate air pollutants and simple air pollutant mixtures	▲				▲
	Investigate effects of elevated photochemical oxidants on various populations	▲				
	Investigate effects of ozone, sulfuric acid aerosol, and nitrogen dioxide on pulmonary function and bronchial reactivity in human subjects	▲ ▲	▲▲			
	Conduct controlled studies of short-term health effects of ozone in people with chronic obstructive lung diseases		▲			
Animal Inhalation Toxicology of Primary and Secondary Pollutants from Energy Systems	Examine effects at the cellular level of intermittent, chronic low-level and acute moderate-level benzene vapor inhalation exposure on immune function in the mouse and marmoset	▲ ▲	▲			
	Determine responses of normal and impaired (elastase treated) guinea pigs to long-term exposures to sulfuric acid and fly ash, alone and in combination	△ △	▲			
	Explore dose-response relationships between impairment of tracheal mucous clearance and acid sulfate concentrations in acute and chronic exposures to dogs, rats, and guinea pigs	△	▲			
	Examine respiratory toxicology following inhalation of NO_x and pulmonary adaptation of inhalation of NO_2	△ △		▲		
	Examine the role of pulmonary lymphatics in particle removal	△		▲		
	Study physical and chemical properties of toxic aerosols and their relation to hazard evaluation	△		▲		
	Examine the pulmonary clearance of particles in animals with altered responsiveness	▲	▲			
	Test the carcinogenic potential of atmospheric toxic gases by studying lung-tumor incidence in mice	△ ▲				
	Develop an early, sensitive biological endpoint that will demonstrate the carcinogenic potential of an environmental pollutant	△			▲	

▲ *Final report, manual or user's guide;* △ *Interim report or manual;* ● *Prototype equipment and report;*
★ *Interim or final criteria formulations;* ○ *Final protocol;* ■ *Continuing effort;* ☐ *Other, self-explanatory*

ENERGY AND ENVIRONMENT RESEARCH PLAN

Energy/Health

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81 82 83 84 85
Animal Inhalation Toxicology of Primary and Secondary Pollutants from Energy Systems	Develop methods to assure long-term release of various classes of compounds in tracheal implants	—▲—▲—▲—▲
	Investigate cofactors that enhance the carcinogenic potential of low levels of chemical carcinogens	△—▲
	Determine if ozone can act as a promoter (carcinogen) in a susceptible (at risk) laboratory animal	▲—▲
	Provide relevant data on the perturbation of respiratory epithelium of laboratory animals by airborne compounds from EPA's hazardous substance list	△—△—▲
	Study health effects on rodents and monkeys of inhaling fly ash, alone and in combination with sulfur dioxide and sulfuric acid aerosol	—▲
	Study effects of inhaled pollutants on physiological parameters of the lung	△—▲
Indirect Assessment of the Toxic Potential of Pollutants Associated with Fossil Fuel Combustion	Evaluate proposed methods for recovering and concentrating trace quantities of waterborne energy pollutants (primarily organic compounds) in sufficiently large quantities for performing short-term *in vivo* animal tests as well as *in vitro* bioassays	—▲
	Develop a mammalian cell culture system for the identification of potential hazardous chemicals that will be reliable, rapid, and inexpensive relative to current animal exposure techniques	—▲
	Develop test systems that will assess the potential hazards of mixtures containing both carcinogenic and noncarcinogenic energy-related pollutants	—△—▲
Extrapolation of Effects of Fossil Fuel Pollutants from Lower to Higher Animals and Humans	Identify and quantify interactions between energy-related toxicants and essential nutrients in a variety of animal species, both normal and nutritionally deficient	△—△—▲
	Define, through interspecies metabolic models, the expected transport and fate of toxic materials in humans	△—△—▲
Health Impacts of Advanced Fossil Fuel Systems	Conduct health assessment studies on new energy and fuels technologies such as coal gasification, coal liquefaction, and oil shale	—▲
	Define and extend a rapid screening procedure to determine the bio-availability of energy-related pollutants in rats	△—△—▲
	Evaluate the role of blood plasma lipoproteins in carcinogen transport, distribution, and fate	△—△—▲

ENERGY AND ENVIRONMENT RESEARCH PLAN

Energy/Health

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Impacts of Advanced Fossil Fuel Systems	Utilize rapid screening genetic assays to identify mutagenic agents associated with coal conversion and oil shale extraction	△	▲	▲	▲	
	Test primary effluents and fugitive emissions of low-BTU gasification processes	▲	▲	▲	▲	
	Conduct biological screening study of shale oil and coal liquefaction operation	▲	▲	▲	▲	
	Utilize mammalian cell culture systems to determine potentially mutagenic and cytotoxic effects of energy-related pollutants from coal	▲	▲	▲	▲	
	Utilize a rapid assay for the identification and purification of neurotoxins and complex mixtures found in fossil fuels	△	△	▲		
	Develop an amphibian assay for teratogenic effects of pollutants derived from synfuel processes			▲		
	Utilize the mouse oocyte screening system to test *in vivo* the cytotoxicity of various energy-related chemicals, as well as complex mixtures from coal gasification and oil shale processing	△	▲			
	Utilize *in vivo* mammalian bioassays of testicular toxicity that are based on the induction of sperm shape abnormalities	△	△	△	▲	
	Detect oil shale-related mutagens using human cell cultures	▲				
	Conduct a synfuel assessment for direct conversion, indirect conversion, and oil shale processes	▲	▲	▲	▲	

ENERGY AND ENVIRONMENTAL RESEARCH PLAN

Transport, Fate, and Effects of Energy-Related Pollutants

PROGRAM OBJECTIVES	**R&D SUB-OBJECTIVES**	FISCAL YEAR 81	 82	 83	 84	 85
Air Pollution Research	Conduct a field evaluation of the effects of air pollution on crop growth and yield			▲	▲	▲
	Evaluate terrestrial ecological consequences of atmospheric emissions from new energy technologies			▲	▲	▲
	Predict effects of air emissions from coal-fired power plants on fish, wildlife, and their habitats			▲	▲	
Alternate Fuels Program Support	Predict groundwater pollution migration for *in situ* oil shale restoring operations		▲	▲		
	Determine effects of pollutants from oil shale mining and processing on freshwater organisms	▲			▲	
	Develop best management practices for protection of topsoil and reclamation of surface mined areas	▲	▲	▲		
	Develop means to reclaim tailings associated with uranium mining		▲	▲	▲	
Acid Rain	Study effects of acid rain on lake systems in Minnesota, Wisconsin, and Michigan		▲	▲		
Oil Spill Research	Investigate ecological hazards of oil spillage	▲		▲		
	Determine fate of toxic substances and their effects on ecosystem processes	▲	▲		▲	
	Examine marine orgnisms for metabolic and toxic effects of hydrocarbons, including PAHs	▲	▲		▲	
	Evaluate the nature and effects of multiple pollutant systems on marine biota		▲			
Freshwater Research	Develop methods to determine fish and wildlife management practices and monitoring procedures on surface-mined land	▲	△	▲		
	Investigate uses of water in energy production			▲	▲	
	Evaluate the transport, fate, and effects of coal ash contaminants		▲	▲	▲	
Coastal Zone and Wetlands Research	Apply ecosystem characteristics to coastal zone projects	▲	▲		▲	▲

ENERGY AND ENVIRONMENT RESEARCH PLAN

Acid Precipitation

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81 82 83 84 85
Monitoring	Provide chemical analysis, maintenance, and quality assurance procedures for acid deposition monitoring sites	——△——▲————▲——▲
	Provide data banking and evaluation for national monitoring program — identify areas affected	————▲—▲——————▲
	Field-validate new dry deposition techniques	——————————△- - -
Acid Deposition Effects	Determine the location of impacted aquatic and terrestrial ecosystems in eastern portion of the U.S.	——▲———▲————▲- - -
	Expand susceptible area identification to western portion of U.S.	——————————▲——▲
	Identify effects on water and sediment chemistry and establish criteria for evaluating nutrient and toxic metal transport in soils and waters	——▲———▲———▲——▲
	Survey lakes, streams, and terrestrial systems to determine impacts	——▲——▲
	Determine impacts on agricultural and forest systems growth, yield and quality, nutrient cycling and ecosystem interactions	—▲——▲———▲————▲—
	Develop and validate models to examine impacts on receptor ecosystems	- - -————————▲——▲
	Assess eastern states data base for lake, stream, soil, and groundwater impacts	——————▲——▲—▲
	Evaluate and assess acid deposition impacts on watersheds	—————▲——▲——▲——▲
	Evaluate impacts on stone, statues, and masonry products	——▲—————▲——▲
	Develop evaluation techniques and damage indicators for materials, including plants, metals, and masonry products	————————▲——▲——▲
	Complete initial assessment of acid precipitation on drinking water	—————▲
	Determine impacts of the release of heavy metals in acidified waters on the quality of tap waters	————————▲——▲- - -
	Evaluate the contamination of groundwater supplies by acid precipitation	————————▲——▲
	Establish a baseline data set on the global extent of acidification of precipitation	——▲
	Conduct dry deposition studies	—▲
Atmospheric Processes	Determine the relationship between air pollution emissions, their transformation and deposition, and the quality of precipitation	————▲——▲—▲—▲- - -

ENERGY AND ENVIRONMENT RESEARCH PLAN
Acid Precipitation

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Atmospheric Processes	Refine emission rates for pollutants containing sulfur and nitrogen		▲		▲	
	Validate and improve trajectory models and develop new acid deposition grid models		▲	▲		▲
	Improve and refine the knowledge and data base for atmospheric neutralizing and catalytic reactions relevant to pollutant transformation and transport		▲	▲		
MAP3S RAINE Scientific Program	Assess program direction	△				
	Conduct wet deposition studies	△				
	Conduct modeling studies	△				
	Conduct dry deposition studies	△				
	Conduct aerosol studies	△				
Mitigation Strategy	Synthesize and interface deposition levels with transport and fate mechanisms throughout various ecosystems of the U.S.			▲	▲	▲
	Identify and analyze technology strategies for mitigation		▲	▲	▲	
	Assess the cost effectiveness of mitigation options for control of sulfur and nitrogen oxide pollutants relevant to acid precipitation			▲	▲	▲
	Assess acid precipitation options relevant to coal supply and transportation				▲	▲

ENERGY AND ENVIRONMENT RESEARCH PLAN

Transport and Transformation of Energy-Related Air Pollutants

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Dispersion, Transport, and Transformation of Energy-Related Pollutants	Develop dispersion model for sources in complex terrain			▲		
	Take field measurements in support of complex terrain modeling	▲				
	Conduct air quality and visibility modeling related to oil shale development	▲				
	Conduct plume blight modeling	▲				
	Carry out Ohio River Valley Study (ORVS)		▲			
Measurement Sources and Instrumentation	Utilize source apportionment models to identify organic particulates from coal conversion processes	△	△	▲		
	Characterize and measure stationary source emissions	▲				
Gas and Inhalable Particulates (GAP)	Develop methods for measuring inhalable (IP) and fine particulates (FP) in source emissions and ambient air	▲	▲	▲		
	Develop source apportionment models for particulates	▲	▲	▲		
	Establish material damage criteria	▲	▲			
	Provide ongoing meteorological support to Agency regulatory programs	□	□	□	□	
Hazardous Air Pollutants	Develop measurement methods for hazardous air pollutants (HAPs)	▲	▲	▲		
	Examine hazardous pollutants processes	▲				
	Develop source apportionment models for HAP	▲	▲			
Oxidants	Investigate oxidant precursors	▲	▲			
	Investigate chemistry and physics of atmospheric oxidant formation	▲	▲		▲	
	Develop and validate photo-chemical air quality simulation models	▲	▲			
	Explore role of natural emissions in oxidant formation		▲		▲	

ENERGY AND ENVIRONMENT RESEARCH PLAN

Monitoring Systems and Instrumentation Development for Energy-Related Water Pollutants

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Groundwater Monitoring Protocols for Coal Strip Mining and Oil Shale Developments	Adapt anticipatory groundwater pollution monitoring technology for application to coal strip mining and oil shale extraction/retorting	▲				
White River Project	Assess impact of organic pollutants from oil shale activities in the White River drainage basin on the quality of White River waters	△	▲▲			
Groundwater Measurement of Contaminant Migration from Hazardous Waste Disposal Sites	Develop a groundwater monitoring system that provides an early warning of hazardous waste leakage at a site used for disposal of hazardous wastes generated by electric utility operations	▲				
	Characterize actual leachates from the Texaco gasification and gas processing facilities at TVA's Ammonia-From-Coal plant	▲				

ENERGY AND ENVIRONMENT RESEARCH PLAN

Fuel Extraction

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Complete Environmental Assessment and Control Technology Development for the Extraction, Beneficiation, and Handling of Coal	Characterize and determine treatment for water discharged from coal slurry pipeline	—	—	▲		

ENERGY AND ENVIRONMENT RESEARCH PLAN

Synthetic Fuel Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Pollution Control and Disposal Evaluations for Oil Shale Activities	Submit first draft of pollution control guidance document for oil shale development	△				
	Complete report describing pollution control technology and removal efficiencies for oil shale wastewaters			▲		
	Design manual for disposal of spent oil shale incorporating RCRA requirements				▲	
	Complete report describing the pollution control technologies and removal efficiencies for gaseous and particulate emissions from oil shale retorting				▲	
	Complete study on revegetation and stabilization of oil shale disposal sites	▲				
	Complete engineering analyses of NH_3/NO_x control technology for oil shale retorts		▲			
	Complete revised pollution control guidance documents for oil shale industry					▲
Pollution Control and Product Utilization Evaluation for Coal Synthetic Fuel Activities	Acquire data on pollutants and control technologies on oil shale, commercial gasification, and liquefaction facilities	▲				
	Prepare pollution control guidance documents for use by regions, states, and industry in design of environmental control on coal and oil shale synfuel plants			▲		
	Assess the magnitude of the problems associated with oil shale and coal synfuel product utilization				▲	
Indirect and Direct Coal Liquefaction	Complete pollution control guidance document for Lurgi indirect liquefaction	▲				
	Conduct environmental analysis of test results at domestic direct coal liquefaction pilot plants (EXXON Donor Solvent, H-Coal)	▲				
	Complete pollution control guidance document for Koppers-Totzek and Texaco indirect liquefaction processes		▲			
	Conduct environmental analysis of test results from SASOL South Africa indirect coal liquefaction plant		▲			
	Complete pollution control guidance document for direct coal liquefaction processes (SRC, H-Coal, EDS)				▲	
	Conduct environmental analysis of test results from SRC-II direct coal liquefaction demonstration plant (Morgantown, W. Va.)					▲
	Conduct environmental analysis of test results from SRC-I clean coal demonstration plant (Catlettsburg, Ky.)					▲

ENERGY AND ENVIRONMENT RESEARCH PLAN

Synthetic Fuel Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Coal Gasification	Complete pollution control guidance documents for low-BTU coal gasification, medium-BTU coal gasification, and Lurgi high-BTU coal gasification	—	▲			
	Develop chemical composition and biological activity data for synfuel products and synfuel combustion	—	—	▲		
	Conduct comprehensive data gathering on a variety of domestic and foreign bench, pilot, demonstration, and commercial synthetic fuel facilities in support of regional, program office, and enforcement activities	—	—	—	▲	
	Continue support for the EPA Regions for Environmental Impact Statements, Prevention of Significant Deterioration reviews, and New Source Performance Standard reviews	—	—	—	—	■

ENERGY AND ENVIRONMENT RESEARCH PLAN

Flue Gas Sulfur Oxide Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Flue Gas Desulfurization Technology Assessment Report to Be Used in 1983-1984 Review of the Utility Boiler NSPS and in Regional Offices for PSD Permitting Review	Complete the assessment of adipic acid additive in a full-scale limestone FGD process to support QAQPS in NSPS-related activities	▲				
	Complete the assessment of spray dryer and alkali injection SO_2 control processes to support QAQPS and OE in both SIP and NSPS cases related to utility boilers	▲				
	Issue FGD technology assessment report for utility boilers	—	▲			
Flue Gas Desulfurization Technology Assessment Report to Be Used in 1985-1986 Review of the Industrial Boiler NSPS and in Regional Office for PSD Permitting Review	Document the operational history, capital, operating and maintenance costs, and performance capability (long and short-term SO_2 removal) of leading FGD systems	—	—	—	—	▲
	Document field evaluation of best commercial FGD units to determine process and Review monitoring system performance data	—	—	—	—	▲
	Issue FGD technology assessment report for industrial boilers	—	—	—	—	▲

ENERGY AND ENVIRONMENT RESEARCH PLAN

Nitrogen Oxide Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Demonstrate Low NO_x Burners and Combustion Modification for Industrial Boiler NO_x Control	Complete first 30-day intensive emission monitoring program on the WIPCO Industrial Boiler Low-NO_x Coal Burner Demonstration Site	▲				
	Install low-NO_x burners and complete second 30-day intensive emission monitoring program at the Industrial Boiler Low-NO_x Coal Burner Demonstration Site	●				
	Complete 18-month demonstration plan at the two demonstration sites		▲			
	Complete pilot-scale evaluation of the 4 million Btu/hour heavy oil burner			▲		
	Complete field evaluation of low-NO_x firing concepts applicable to stoker-fired industrial boilers			●		
Demonstrate Low-NO_x Burners and Combustion Modification for Industrial Boiler NO_x Control	Install low-NO_x burners and complete first 30-day intensive emission monitoring program on a single wall-fired utility boiler (coal-fired)	●				
	Install low-NO_x burners and complete first 30-day intensive emission monitoring program on an opposed wall-fired utility boiler (coal-fired)	●				
	Complete low-NO_x burner design and application guidelines manual for utility boilers			▲		
	Install the rich fireball combustion system on a state-of-the-art tangentially-fired utility boiler (coal-fired) and complete evaluation and guideline manual		▲			
LIMB (Limestone Injection Multistage Burner) SO_2/NO_x Control Program	Complete bench- and pilot-scale evaluation of the limestone injection into the distributed mixing burner (LIMB) simultaneous SO_2/NO_x control process		●			
	Complete 30-day optimization tests for the LIMB process on a wall-fired boiler and initiate the 18-month evaluation program		□			
	Complete 30-day optimization tests for the LIMB process on a wall-fired boiler and initiate the 18-month evaluation process		□			
	Document the performance and capital and operating costs of the limestone injection through the multistage burners for potential use in an acid rain control strategy				▲	

ENERGY AND ENVIRONMENT RESEARCH PLAN

Gas Particulate Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Reports on Field Measurements of Inhalable (IP) Emission Factors for Primary Nonferrous Smelters, Paved and Unpaved Roads, Cement and Lime, and Pulp and Paper Industries for Setting Federal Guides for Developing SIPs in Non-attainment Areas	Complete characterization of IP emissions for primary nonferrous smelters and issue problem-oriented report and project report	▲				
	Complete characterization of IP emissions from paved and unpaved roads and issue problem-oriented report and project report	▲				
	Complete characterization of IP emissions for pulp and paper industry and issue problem-oriented report and project report	▲				
	Complete characterization of IP emissions for cement and lime industry and issue problem-oriented report and project report	▲				
	Complete characterization of IP emissions for coal combustion and issue problem-oriented report and project report		▲			
	Complete characterization of IP emissions for iron and steel industry and issue problem-oriented report and project report		▲			
Design, Construction, and Installation for Evaluation of a 10 MW Pilot High-Resistivity Pre-charger ESP as Low-cost Particle Control for Low-sulfur Coal-burning Utility Boilers to Meet Revised NSPS, PSD, and SIP Requirements	Complete design of transportable ESP	●				
	Complete first evaluation report		▲			
	Complete shakedown of transportable ESP		□			
	Complete first field test using transportable ESP			□		
	Complete evaluation report for industry covered by transportable ESP test				▲	
Particulate Control Technology Assessment for New Source Performance Standard Support	Report on Southwest Public Service full-scale baghouse demonstration of a fabric filter for low-sulfur coal and fly ash emission control to provide an initial base for NSPS, SIP, and PSD determination	▲				

ENERGY AND ENVIRONMENT RESEARCH PLAN

Conventional Combustion Environmental Assessment

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Determination of Polycyclic Organic Matter Emissions from Coal, Oil, and Derived Fuels by Combustion Source Technology	Complete the work plan for the HAP and polycyclic organic matter (POM) assessment program	▲				
	Complete draft report on initial evaluation of controllability of HAP from various fuels and combustion sources	△				
	Issue first annual report on emissions and controllability assessment of HAP from various fuels and combustion sources		▲			
Wood Combustion Environmental Assessment Program	Complete emissions characterization of a wood-fired industrial boiler	▲				
	Issue final report assessing current knowledge on wood combustion emissions, control approaches, and impacts	▲				
	Issue final report on source test results to compare emissions from the combustion of wood, coal, peat, and other fuels in woodburning stoves	▲				
	Issue final report comparing POM emissions from industrial, commercial, and residential combustion of wood		▲			

HAZARDOUS AIR POLLUTANTS

The focus of EPA's Hazardous Air Pollutant Research Program is on the identification, evaluation, regulation, and control of airborne carcinogens. Researchers are challenged by the uncertainties involved in this quest, a challenge, nonetheless, being met by the Agency as evidenced by its publication of a proposed air carcinogen policy in the Federal Register. Significant problems remain, however. Uncertainties in the existing information on known air pollutants must be identified and resolved, affirmative determinations of carcinogenicity must be supported, large numbers of potential carcinogenic compounds must be effectively screened, and appropriate control levels for sources of hazardous air pollutants must be established. Playing a key role in focusing research into these areas has been the Hazardous Air Pollutant Research Committee.

Also of concern to the Committee is the program's second priority research effort, e.g., hazardous air pollutants that have non-carcinogenic toxic effects.

EPA's primary regulatory mechanism for controlling airborne carcinogens and other hazardous air pollutants is Section 112 of the Clean Air Act, although toxic compounds can also be regulated through the Toxic Substances Control Act and the Resource Conservation and Recovery Act supplement. Titled "National Emission Standards for Hazardous Air Pollutants," Section 112 defines "hazardous air pollutant" as:

> *an air pollutant to which no ambient air quality standard is applicable and which in the judgment of the Administrator causes, or contributes to, air pollution which may reasonably be anticipated to result in mortality or an increase in serious irreversible, or incapacitating reversible, illness.*

Section 112 requires listing of such hazardous pollutants and control of stationary sources emitting them. Currently seven pollutants are listed.

In addition, Section 111d of the Act allows regulation of certain hazardous air pollutants that are associated with specific source categories. Considered "designated pollutants," those currently listed include sulfuric acid mist, fluorides, and total reduced sulfur compounds from kraft pulp mills.

What is today thought of as EPA's proposed air carcinogen policy originated during 1980 as a document entitled "National Emission Standards for Hazardous Air Pollutants; Policy and Procedures for Identifying, Assessing, and Regulating Airborne Substances Posing a Risk of Cancer." The document proposes rulemaking that would govern Agency policy and procedures used to identify, assess, and regulate substances emitted from stationary sources into the ambient air that would increase the risk of cancer to the general population.

Over the past year and a half, preliminary implementation of the policy has included unit risk determinations—the risk of developing cancer associated with a continuous lifetime exposure (70 years) to a unit concentration (1 microgram per cubic meter) of a subject pollutant—for three high-volume industrial solvents (trichloroethylene, perchloroethylene, and acrylonitrile) and for seventeen other carcinogens being ranked for priority action by the air program regulatory office. In addition to unit risk determinations, estimates of nationwide exposure of the population to the three compounds were also carried out. These assessments and the manner in which they were performed illustrate the policy and procedures of air carcinogen policy being proposed by the Agency.

HAZARDOUS AIR POLLUTANT RESEARCH PROGRAM

ORD's Hazardous Air Pollutant Research Program is directed toward:

- implementing the air carcinogen policy;
- supporting the General Airborne Toxic Materials Program; and
- supporting the EPA Regional Offices and technical information dissemination.

Research projects conducted under the auspices of the Hazardous Air Pollutant Research Program improve the scientific basis for establishing cause and effect relationships between hazardous airborne pollutants and potentially-related disease. By improving our understanding of these relationships, we will strengthen our support of EPA's efforts to regulate and control air pollutants, especially airborne carcinogens. Research toward the policy's implementation will include identification, screening, and preliminary carcinogenicity assessments of high-production volatile organic chemicals, more detailed

NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

POLLUTANT	STATUS
MERCURY	PROMULGATED
BERYLLIUM	PROMULGATED
ASBESTOS	PROMULGATED
VINYL CHLORIDE	PROMULGATED
BENZENE	LISTED, REGULATIONS CURRENTLY UNDER REVIEW
RADIONUCLIDES	LISTED
ARSENIC	LISTED

assessments of those chemicals which show a high potential for carcinogenicity, support for regulatory decisions, and review of existing regulations under Section 112 of the Clean Air Act.

The overall research effort is divided into four categories:

- ambient air characterization;
- source and emissions characterization;
- evaluation of general toxicity of hazardous air pollutants; and
- assessment of the hazardous effects of pollutants in exposed populations.

Ambient Air Characterization

The release into the atmosphere of a large number of potentially harmful organic chemicals may be related to a wide spectrum of carcinogenic and non-carcinogenic human health effects. EPA has just begun to develop a detailed chemical inventory of toxic materials in ambient air. The inventory will identify the amounts of hazardous air pollutants already in ambient air and the levels of human exposure to these airborne toxics. At present, however, several problems slow the development of the inventory. These include the large number of potential hazardous air pollutants that need to be analyzed, sampling and analytical techniques insufficient for accurate characterization of ambient air levels, and imprecise models to represent the complex atmospheric transport and transformation relationships of the airborne pollutants. In support of the inventory effort and to supplement results from laboratory studies of atmospheric chemistry that will assess the transport processes and atmospheric fate of potentially dangerous chemicals, ORD is gathering data on emissions trends and variability of ambient air levels of a number of organic gases and vapors in wide use today in America.

Near-term research objective for ambient air characterization are:

- to characterize the abundance and variability of methylene chloride, vinylidene chloride, and other selected toxic organic chemicals in urban environments such as Los Angeles, Phoenix, and Oakland, California;
- to investigate and assess the atmospheric fate of the toxic organics, to include measurement, modeling, and prediction of their chemical behavior in the atmosphere from source to eventual sink; measurements and modeling will be done in compliance with the EPA mandatory quality assurance program; and
- to determine the extent of human exposure to airborne toxic chemicals.

Timely and cost-effective approaches will be used to achieve research objectives. New or improved analytical procedures for collecting samples of the hazardous air pollutants will be developed and standardized as will the techniques for chemically analyzing the toxic chemicals in the samples. To develop a valid data base for ambient levels of toxic chemicals and to provide a better understanding of the atmospheric fates of these chemicals, measurements of the atmospheric concentrations of selected toxicants will be made at several representative locations. This data will then be integrated with estimates of chemical production rates and subsequent emissions in order to arrive at predictions of atmospheric abundance, fates, and health effects of the toxicants in question. Data will be continually updated, validated, and assimilated into an organized data base gathered from EPA, other government agencies, and literature searches. Thus structured, the data can be used directly to analyze the proposed listing of a chemical for regulation and control under Section 112 or 111d.

Source and Emissions Characterization

Source characterization measurements for hazardous air pollutants are necessary to identify current problems as well as to call attention to those sources that could become problems in the future. An environmental assessment of a small pilot-scale coal liquefaction plant, for example, may find the potential for small fugitive leaks of polycyclic aromatic hydrocarbons from the plant. While the amounts of emissions from such a small development facility may not pose a hazard to public health, scale-up and construction of one or more commercial facilities based on the same process could conceivably present a significant potential problem. Potential problems may also be posed by existing sources that presently emit acceptable levels of potentially hazardous materials. Such problems could arise, for instance, if emissions suddenly exceed danger levels as a result of control systems malfunction. Research to determine such potential sources and the pollutant amounts each source loads into the ambient air is currently under way. Future plans include continued source characterization measurements and modeling of the ambient concentrations contributed by each source.

Two categories of new potential sources to be added to the research will be coal conversion (synfuels) plants and industrial waste disposal technologies. Both are being added because expected trends show likely increases in future emissions from these sources.

Coal conversion plant sources will be of particular research interest in light of the fact that early data indicate that some intermediate and end products from such facilities that produce both gaseous and liquid fuels have high potential for mutagenicity and toxic health effects. Of equal importance will be the characterization of emissions from industries switching from petroleum feedstocks to coal and coal-derived feedstocks, a conversion that may result in an altogether new family of emissions of unknown toxicity.

Hazardous waste incineration technologies also will be studied. Research will focus on ensuring that thermal destruction of hazardous compounds is sufficient to preclude the release of pollutants through vaporization, chemical rearrangements of the wastes to other toxic forms, and unintended dispersal into the air. Improving our ability to economically screen and detect low concentrations of potentially hazardous compounds, however, will affect the direction of future regulatory and research programs for the incineration of hazardous air pollutants. For example, co-disposal by incineration of sludges and industrial solid wastes that contain cadmium and other heavy metals may increase the risk of exposure to airborne toxics, and, with better screening and detection methods, we may be able to better identify the risks. Thus, this issue of intermedia trade-off will be better defined by characterizing hazardous air pollutants resulting from waste incineration and weighing the risks from them against alternate solid waste or water quality impacts. Because the incineration alternative may prove to be more hazardous, comparative assessment with current landfill practices will also be carried out. In addition, resource recovery alternatives that use hazardous wastes as fuels will be studied to ensure that the benefits of the recovery are not outweighed by the risks of potential combustion by-products.

The objectives of the source characterization research are:

- to develop source sampling and analytical techniques with appropriate quality assurance that adequately separate and characterize airborne emissions of potentially hazardous materials;
- to prepare comprehensive environmental assessments of industrial point sources, fugitive emissions, conventional combustion sources, and emerging coal conversion technologies such as indirect and direct liquefaction of coal. Assessments will make use of up-to-date and sophisticated sampling equipment for the most efficient capture of particulates and volatile hazardous materials emissions. Likewise, the most sensitive analytical detection techniques will be used to identify and quantify hazardous materials captured from emissions streams; and
- to inventory hazardous air pollutants being emitted from specific source categories. Data of known quality will be processed into ORD's recently developed Environmental Assessment Data System (EADS) for efficient cataloging, storage, and retrieval.

Evaluation of General Toxicity of Hazardous Air Pollutants

To date, Section 112 of the Clean Air Act, which calls for the establishment of a list of hazardous compounds, has been primarily directed toward airborne agents which are potentially carcinogenic. By illustration, of the four compounds now listed as hazardous, only one, mercury, was listed because of its non-carcinogenic toxic properties. This focus on carcinogens is due, in part, to the fact that policies and risk assessment procedures have not yet been well enough defined for dealing with the numerous non-carcinogenic toxicity end points that must be considered under Section 112.

However, this is not to infer that non-carcinogenic toxicants pose a lesser problem. To the contrary, the occurrence of non-oncologic diseases has enormous impact on the health of the United States population. In 1975, for example, the prevalence of such non-carcinogenic conditions totalled approximately 148.7 million cases; respiratory disease, 46.8 million, cardiovascular disease (the leading cause of death in America), 36.4 million; skin conditions, 25.2 million; conditions of genitourinary, nervous, endocrine, and blood-forming systems, 23.3 million; and digestive conditions, 17.0 million. An additional 30 million people suffered some degree of limitation as a result of a chronic disease. The cost of caring for these people is enormous: the price tag for diseases of the circulatory system was about $50 billion; for diseases of the respiratory system the cost was $20 billion. Our research programs in this area are aimed at describing the fraction of these diseases that is attributable to hazardous air pollutants, because even a small reduction in the incidence of these chronic diseases could result in large economic gain to the society, as well as significant reductions in human suffering.

Our current research into non-carcinogenic compounds involves the gathering of the data required to establish policies and risk assessments to reduce the incidence of disease from toxic air pollutants. One major information source for evaluating human health risks from air pollution will be animal exposure studies. We are currently determining the types of animal studies available, the most reasonable sequence of experimentation, and the costs of each level of effort. Because of the large volume of chemicals to be tested, cost-effective toxicity test methods must be employed. Tests must also be sophisticated enough to reveal any potentially serious effects toxic chemicals may have on human health, and testing procedures must be sufficiently flexible to accommodate a broad spectrum of chemicals. Testing will be designed to generate information useful for hazard evaluations, and to provide concentration-response relationship data for establishing or predicting a no-effect level of exposure.

Five levels of testing are of interest to the Hazardous Air Pollutants Committee. Lower level testing represents the most reasonable, early-predictive tests that would be rapid, comprehensive, and low cost. The higher levels represent more sensitive and specialized tests for risk assessments of selected compounds to determine no-measureable-effect levels. Deciding the appropriate test level, cost, or performance time requires an individual evaluation of each compound based on information obtained in lower-level tests. Decisions will be made by EPA research personnel, an advisory panel of toxicologists, and members of OAQPS. The testing protocol that is decided upon must be sufficiently comprehensive to apply to a variety of chemical agents, including simple and complex mixtures such as gases, vapors, particulates, liquids, and other physical and chemical forms.

Assessment of the Hazardous Effects of Pollutants on Exposed Populations

In order to prevent harmful exposure to environmental agents, EPA regulations must be directed toward situations which are known to be hazardous. This requires a realistic assessment, for chemical agents of concern, of the types of adverse health effects that can be expected, the amount of human exposure that is likely to cause these effects, the exposure that is likely to occur under actual environmental conditions, and the reduction in hazard that is likely to occur if a particular regulation is implemented. This assessment must be supportable in public forums, and structured in such a way that a defensible decision can be formulated.

An assessment of this type combines into a comprehensible hazard analysis all relevant biological and ecological research results, monitoring surveys, data from environmental fate and transport models, human epidemiology studies, and analyses of demographic patterns. The key elements of the analysis are:

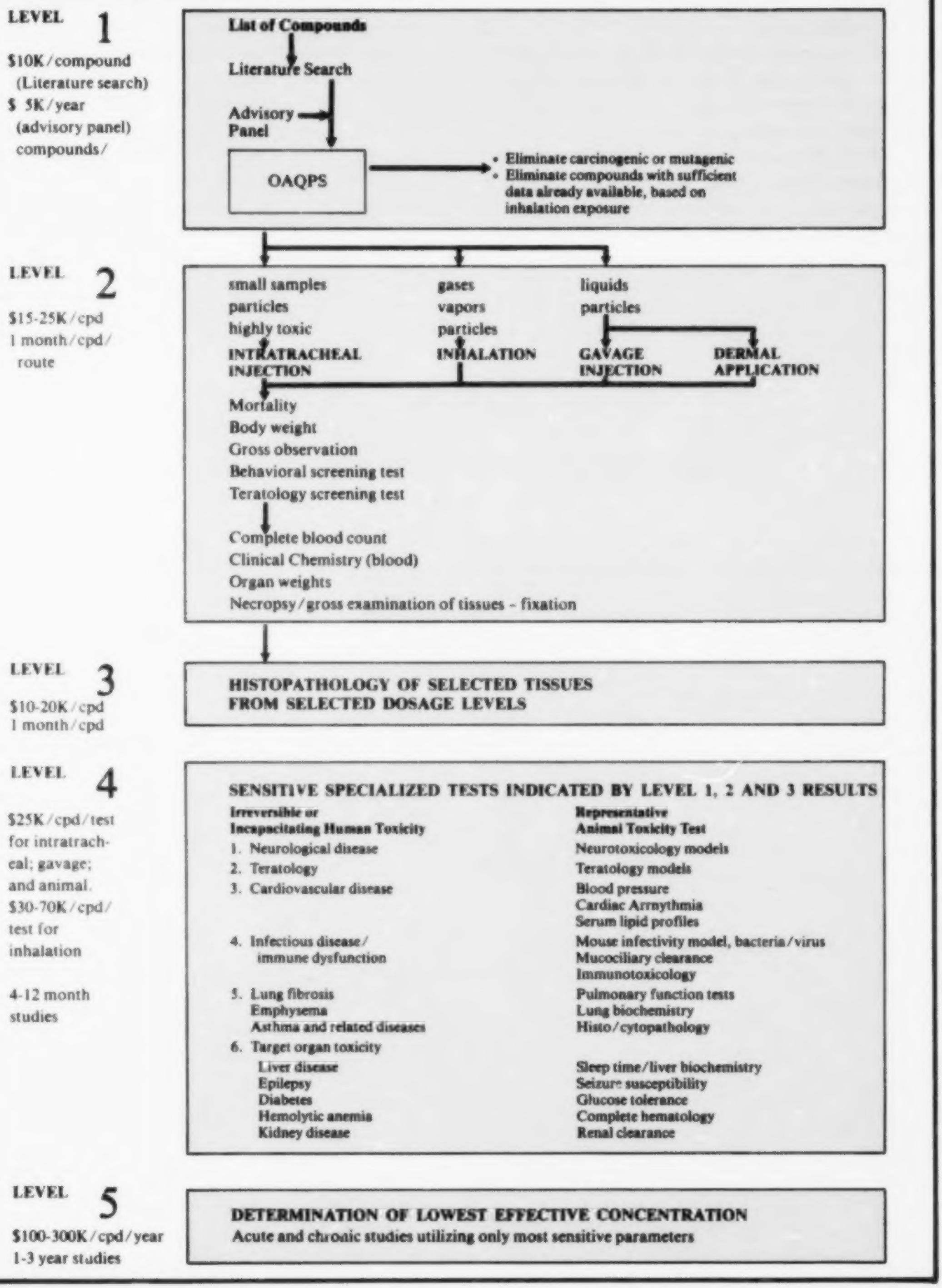
- a determination of the likelihood that the chemical in question causes cancer, mutations, birth defects, or neurological, pulmonary, or other toxic effects;
- a determination of the dose-response relationship for each suspected or demonstrable effect; and
- an evaluation of the magnitude of human environmental exposure based on actual monitoring data, and on data from models designed specifically to predict these exposures.

EXPECTED TRENDS IN HAZARDOUS AIR POLLUTANTS

It is expected that by the year 2000 the nation will experience a substantial increase in the quantities of hazardous materials being released into the environment. This assumes a nominal 6 percent growth rate for chemical industries and no change in the regulatory trend towards the chemicals. This increase is further complicated by the fact that currently about 500 new chemical substances are being introduced annually into the marketplace, many of which may also be hazardous. In order to control these new chemicals and those already known to pose threats, more information is needed regarding the interaction of these chemicals with the environment and their impacts on human health. Because of the large number of potentially hazardous compounds involved, a data base will have to be developed capable of tracking the amounts of these compounds being produced and used, and pinpointing the respective locations of production and usage. This will facilitate exposure assessment to the population at risk.

For those chemicals found through research to be substantially hazardous, regulations must be promulgated to either limit their production or control emissions that result in human exposure. If additional controls and regulations to contain or abate hazardous air pollutants are not forthcoming, however, the

EVALUATION OF THE GENERAL TOXICITY OF HAZARDOUS AIR POLLUTANTS


LEVEL 1
$10K/compound (Literature search)
$ 5K/year (advisory panel) compounds/
List of Compounds
Literature Search
Advisory Panel
OAQPS
• Eliminate carcinogenic or mutagenic
• Eliminate compounds with sufficient data already available, based on inhalation exposure
LEVEL 2
$15-25K/cpd
1 month/cpd/route
small samples
particles
highly toxic
INTRATRACHEAL INJECTION
gases
vapors
particles
INHALATION
liquids
particles
GAVAGE INJECTION
DERMAL APPLICATION
Mortality
Body weight
Gross observation
Behavioral screening test
Teratology screening test
Complete blood count
Clinical Chemistry (blood)
Organ weights
Necropsy/gross examination of tissues - fixation
LEVEL 3
$10-20K/cpd
1 month/cpd
HISTOPATHOLOGY OF SELECTED TISSUES FROM SELECTED DOSAGE LEVELS
LEVEL 4
$25K/cpd/test for intratracheal; gavage; and animal.
$30-70K/cpd/test for inhalation
4-12 month studies
SENSITIVE SPECIALIZED TESTS INDICATED BY LEVEL 1, 2 AND 3 RESULTS
LEVEL 5
$100-300K/cpd/year
1-3 year studies
DETERMINATION OF LOWEST EFFECTIVE CONCENTRATION
Acute and chronic studies utilizing only most sensitive parameters

Irreversible or Incapacitating Human Toxicity	Representative Animal Toxicity Test
1. Neurological disease	Neurotoxicology models
2. Teratology	Teratology models
3. Cardiovascular disease	Blood pressure Cardiac Arrnythmia Serum lipid profiles
4. Infectious disease/immune dysfunction	Mouse infectivity model, bacteria/virus Mucociliary clearance Immunotoxicology
5. Lung fibrosis Emphysema Asthma and related diseases	Pulmonary function tests Lung biochemistry Histo/cytopathology
6. Target organ toxicity	
Liver disease	Sleep time/liver biochemistry
Epilepsy	Seizure susceptibility
Diabetes	Glucose tolerance
Hemolytic anemia	Complete hematology
Kidney disease	Renal clearance

following increases by the year 2000 over 1975 pollution levels are anticipated:

- a 67% increase in amounts of asbestos mined in the United States;
- a 481% increase in the production of polyvinyl chloride (the end product of essentially all vinyl chloride produced) and a 207% increase in the amount of benzene produced;
- a 700 to 800% increase in uranium ore mined and processed in the United States;
- a 57% increase in the amount of pesticides and herbicides (of which arsenic compounds are a major by-product) produced in the United States; and
- a 70% increase in the demand for cadmium in the United States.

The implications of such significant increases, along with the uncertainties surrounding the effects of airborne toxic chemicals, points to the need for a continued research program designed to identify hazardous air pollution problems and provide a data base sufficient to justify the regulation of the sources responsible for those problems.

HAZARDOUS AIR POLLUTANTS RESEARCH PLAN

Regulatory Decision Making

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Support for Regulatory Decision Making	Conduct field trials of benzene destruction in thermal oxidation units	Δ	▲			
	Perform systems analysis of control of hazardous pollutants from small sources		Δ	▲		
	Evaluate hazardous air emissions from industrial wastewater ponds			▲		
	Conduct performance evaluation of activated carbon adsorption units		▲			
	Assess use of flares to control hazardous and oxidant air pollutants		▲			
	Develop formaldehyde-free finish for textile fabrics			Δ	▲	

▲ Final report, manual or user's guide; Δ Interim report or manual; ● Prototype equipment and report;
★ Interim or final criteria formulations; ○ Final protocol; ■ Continuing effort; □ Other, self-explanatory

HAZARDOUS AIR POLLUTANTS RESEARCH PLAN

Source and Emissions Characterization

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Screening and Identification	Report on the precision and accuracy of the data from ambient air chemical characterization field studies of hazardous air pollutants and the development of an air monitoring strategy	▲				
Risk Assessment	Report on the persistence, degradation products, and fate of selected hazardous air pollutants		▲		▲	
	Provide a data base of long-term ambient monitoring of high priority hazardous air pollutants for use in modeling growth patterns and seasonal variations		△	△	△	△
General Category	Report on the characterization of carbon fibers emitted from manufacturing, processing, and disposal facilities	▲				

HAZARDOUS AIR POLLUTANTS RESEARCH PLAN

Monitoring Systems and Quality Assurance

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Identification and Screening	Field-collect particulate matter from Massive Air Volume Sample (MAV) for bioassay and chemical characterization				□	
Risk Assessment	Perform monitoring and field studies on specific priority pollutants to verify exposure estimates in the vicinity of sources				□	
Regulatory Decision Making	Evaluate provisional method for asbestos		▲			
	Evaluate, validate, and standardize 2 methods per year for NESHAP ambient air		□	□	□	
	Evaluate and validate 2 methods per year for stationary source emissions		□	□	□	
	Evaluate continuous emission monitors (CEMs) as compared with Manual Compliance Methods				▲	
General Category	Equip and operate a Standards Laboratory for hazardous air pollutants—add new standards traceable to NBS				□	

HAZARDOUS AIR POLLUTANT RESEARCH PLAN

Risk Assessment

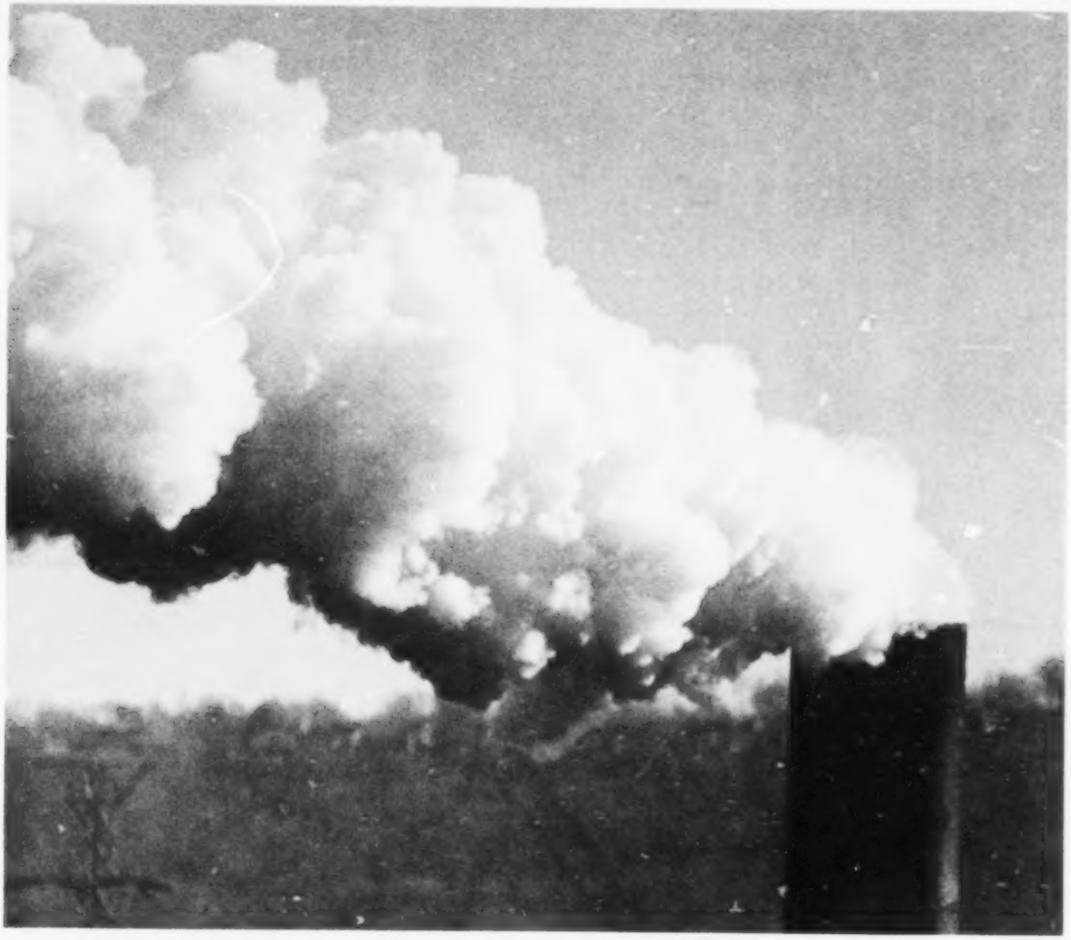
PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Risk Assessment	Complete carcinogenicity evaluations with unit risk estimations on approximately 20 chemicals for Sections 112 and 122 use for possible listing as hazardous air pollutants	□	□	□	□	□
	Complete mutagenicity evaluations and/or separate risk analyses for 6 of the 20 cancer-causing chemicals to support the Agency's cancer policy or other hazardous materials decisions	□	□	□	□	□
	Provide exposure assessment reviews and/or technical assistance using the new Agency guidelines for up to 9 Type II assessments or other situations	□	□	□	□	□
	Complete comprehensive health assessments on methylene chloride, fluorocarbon 113, trichloroethylene, methyl chloroform, tetrachloroethylene, ethylene dichloride, acrylonitrile, vinylidene chloride, and arsenic as required by Sections 111(d) and 112 of the Clean Air Act	▲				
	Initiate a health assessment document on toluene both for OAQPS and the TSPC	□				
	Initiate and/or complete health assessments on 3-5 new chemicals to be selected by OAQPS	▲	▲	▲	▲	▲

HAZARDOUS AIR POLLUTANTS RESEARCH PLAN

Health Effects

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Effects	Determine relationship between cancer mortality and ambient asbestos measurements in chrysotile asbestos mining counties	△	▲			
	Develop biochemical indicators of neurotoxicity			▲		
	Evaluate rodents used to test effects of particulant feed and waste streams from industrial and energy processes (acute *in vivo* tests and reproductive evaluations)	▲ ▲	▲	▲		
	Publish material on cancer mortality rates and trends (1950-1978)	▲ ▲				
	Determine effects of selected chemicals on trachea epithelia	△	▲			
	Report on the use of an intratracheal infectivity model to screen hazardous compounds for priority in inhalation testing	▲				
	Report on the effects of toluene exposure on susceptibility of animals to respiratory infection and on prolongation of pentobarbital-induced sleeping time	▲				
	Report on effect of acute exposure to arsenic on susceptibility of animals to respiratory infection	▲				
	Report on the mutagenic activity of potentially hazardous classes of chemicals detected in urban air on the 1980-81 pilot studies	▲				
	Report on 10 to 15 hazardous compounds (to be selected) tested in an intracheal infectivity model		▲			
	Report on the effect of phosgene inhalation on respiratory infection, host defense systems, and edema formation		▲			
	Report on the mutagenic and carcinogenic activity of specific chemicals identified as a result of bioassay screening and characterization of urban ambient air		▲			
	Final report on effects of selected hazardous pollutants on susceptibility to infectious disease in man			▲		
	Determine effects of lead in central nervous system electrophysiology of children		△		▲	
	Initiate bioassay-directed source characterization study to identify air carcinogens emitted from selected sources		■	■	■	

GASES AND PARTICLES



The gases and particles research program is concerned with three major air pollutants—particles, sulfur dioxide, and lead. These pollutants may damage crops, reduce visibility, and cause or contribute to respiratory infections, asthma, emphysema, bronchitis, neurologic disorders, and other acute and chronic diseases. When transported long distances, the pollutants can be transformed into other pollutants that also adversely affect human health and welfare.

Sound scientific information is needed to determine the adequacy of existing air quality standards for these pollutants, to establish new standards, and to control pollution emissions. The current gases and particles research program is designed to produce the required information. Six specific areas are of interest to the research program: (1) health effects; (2) air quality model development; (3) monitoring instrumentation and quality assurance; (4) welfare effects (which include all non-health related effects such as effects on crops and ecosystems, materials damage, and reduced visibility); (5) source characterization; and (6) control technologies development. Of the six areas, however, development of control technologies is treated much more extensively in the energy research program and is therefore discussed in Chapter 2, "Energy and Environment."

THE RESEARCH PLAN

Air quality standards promulgated under the Clean Air Act are now undergoing review for possible revision. Since gases and particles research results contributed significantly to the criteria for the initial standards, they will be a prime source of data for the current review and for future reviews to be held at five-year intervals. Our research, therefore, is planned to be in phase with this review cycle. On a continuing basis, our research also supports implementation of other important provisions of the Clean Air Act such as Prevention of Significant Deterioration (including visibility protection), New Source Performance Standards, and evaluation of State Implementation Plans.

The research will emphasize health effects and atmospheric model development; lesser but still significant efforts will be devoted to monitoring and welfare effects. The health effects research will continue to conduct animal toxicology and clinical studies to determine both chronic and acute effects of particles and SO_2. Respirable particles in both coarse and fine modes will receive the most attention because good quantitative estimates of the health effects from either primary or secondary particulate air pollution are not available.

The modeling research will continue its study of regional air pollution problems. Regional models are needed to assess the environmental effects of given sources over long distances. These models will become of increasing importance as EPA addresses problems of visibility degradation, acid precipitation, and interstate air pollution. (Acid precipitation research is covered in more detail in Chapter 2.) Development of reasonable control strategies will depend heavily on modeling results.

The monitoring work will continue to follow a dual research path: One effort involves the continuation of a network of sampling stations for inhalable particles, the other the development of personal monitoring devices that will detect and measure an individual's direct exposure to particulate air pollutants. The welfare effects research starting in 1984 will emphasize the assessment of SO_2 effects on crops.

At the appropriate point in the research and regulatory development cycle, ORD will conduct an update of the lead criteria document, which establishes the scientific health effects basis for a revision to the standard. A similar effort is under way now for an SO_x/particulate matter criteria document.

Health Effects Research

To establish data for future reviews of air quality standards for sulfur oxides and particles, the health effects research under the Gases and Particles program will attempt to find answers to seven specific questions:

- Which of the various SO_x/particle species cause adverse health effects and what are their chemical composition and size distribution?
- Are these effects caused by the individual pollutants or pollutants in combination with others? If in combinations, which ones?
- What is the threshold level of exposure to SO_x/particles at which acute effects can be observed in humans and what are the effects at or around that level?
- Does the early appearance of acute or other more subtle effects signal later expression of chronic effects?
- At what levels of exposure over what period of time are chronic effects to be expected?
- What are the acute and the chronic effects of exposure to these pollutants?
- How do surrounding conditions other than pollutant exposure and pre-existent health problems influence people's responses to pollutant exposure?

In the projects designed to answer these questions, we will study sulfur oxides and airborne particles together to determine if one enhances the effects of the other.

The health effects studies fall into two broad categories: animal toxicology, and clinical.

Animal toxicology studies. Animal studies will be designed to simulate acute and chronic human responses to air pollution and to establish hypotheses that will be tested in epidemiological studies. Acute effects data will be derived from studies that expose animals for one 4- to 5-hour period; three levels of pollutant concentration will be used—each with a different group of animals. Chronic effects data will come from intermittent and long-term exposure studies. The intermittent studies will expose animals to three pollutant concentrations for seven hours per day for three to four weeks; the longer-term studies will use only one exposure concentration but it will be for seven hours per day over a six month- to two-year period.

Since the results of all three types of studies—acute, intermittent, and long-term—will take the form of a concentration-response curve, the precise concentrations to be studied cannot yet be determined. At present, however, emphasis will be on concentrations near or below the standard (1 mg/m^3) so that results will be useful for judging the adequacy of the standard. The data gathered from the acute and intermittent studies will be used to determine exposure ranges for the chronic effects studies and for studying effects that ethically cannot be studied in people. Acute effects data will thus be correlated with data from human clinical studies; the data also will be used for evaluating the averaging time for acceptable pollution concentrations in existing and possible future short-term air quality standards. Results from the chronic studies will support establishment or revision of a longer-term standard.

Animal toxicology studies now being conducted will determine acute and chronic effects of exposure to "coarse mode" particles, 2.5-15 μm mean aerodynamic diameter (MAD), and "fine mode" particles, 1-2.5 μm MAD. Particle species are being tested alone, in combination, and in the presence of other pollutant gases such as ozone, SO_2, and NO_x. The research will compare pollutant effects on normal, healthy animals with effects on: (1) animals treated with pharmacologic agents (e.g., histamine) to simulate upper respiratory disease (e.g., asthma) in order to characterize the potential for constricting the animal's bronchial airway in response to pollutant exposure; (2) animals treated with elastase to simulate lower respiratory disease (e.g., emphysema); and (3) Syrian hamsters that spontaneously develop congestive heart failure. In each of the studies, we plan to follow a full range of biological system parameters, singly and in combination with one another. The parameters are:

- pulmonary function, including airway reactivity, airway resistance, air flow rates, and pulmonary volume;
- cardiovascular function, including heart rate and efficiency, electrocardiogram, and blood flow rates and volume;
- biochemistry, including balance of serum electrolytes, proteins, and indicators of liver and kidney function;
- hematology, including indicators of red and white blood cell number, structure and function, oxygen-carrying capacity, and blood clotting;
- immunology, including host defenses against infectious or neoplastic (tumor initiation and growth, both benign and cancerous) disease;
- histopathology (microscopic pulmonary tissue structural changes);
- xenobiotic pharmacokinetics (alteration or potentiation of drug effects by exposure to pollutants).

Clinical studies. In the clinical studies, healthy college student volunteers will be employed in 20 exposure chamber studies. Each study will involve 15 subjects who will be exposed to a specific combination of pollutants and compared with non-exposed cohort controls. Exposure time will be four to six hours, including periods of rest and exercise, under both standard and elevated conditions of temperature and humidity. These cohort exposures will be randomized to eliminate season variables. The pollutants will be fine mode aerosols, tested alone and in combination with other gases.

Each subject in the study will be profiled according to demography, non-pollutant environment, and measured pollutant exposure pattern. Before, during, and after the exposures, we will measure each subject's body plethysmography (air and heat exchange rates), pulmonary function, airway response to pharmacologic bronchoconstrictor dose (PDAR), cardiovascular function, biochemistry, hematology, immunology, and symptoms. Subjects who are considered to be particularly susceptible to effects from air pollutant exposure—including patients with asthma, chronic bronchitis, emphysema, and cardiovascular disease—also will be studied.

The clinical studies will produce data about acute but reversible effects in humans caused by exposure to sulfur oxides and particles. The data will help determine appropriate short-term air quality standards and will provide baseline information for the development of equipment and approaches to be used in possible epidemiological studies.

Air Quality Model Development

Air quality model research focuses on the sources, transport, transformation, dispersion, and deposition of sulfur oxides and particles of various chemical compositions. Much of this research—notably short- and long-range air quality models for various sources, terrains, and meteorological conditions—is similar in approach to research conducted for the Hazardous Air Pollutants Research Committee and for the Oxidants Research Committee (see Chapters 3 and 5). Modeling for acid deposition is conducted under the Energy and Environment research program and is discussed in Chapter 2. The gases and particles research emphasizes the development of air quality simulations to model emission/receptor relationships of SO_2, sulfate particles, organic aerosols, and soot. The research is coordinated with the other related work by a special subcommittee on atmospheric modeling.

STATUS OF CLASS I AREA VISIBILITY IMPAIRMENT[a]

Region	Number of class I areas	Reported visibility status[a]	Observed visibility[a] phenomena	Potential sources[a]		Potential for future impairment[a-e]
				Man-made	Natural	
West of 100° Meridian						
Pacific Northwest	30	Generally desirable visibility, intermittant undesirable conditions	1. Smoke, haze 2. Visible plumes	1,2. Agricultural burning; slash burning; forest products industry; pulp, paper mills; saw mills; Al, Cu smelters; urban plumes; prescribed burning	1,2. Wildfires; fog	Small increase in utility, industrial coal use;[b,c] population growth[d]
California (excluding North):						
West Coast Central Valley	7	Generally impaired outside areas, some impairment in areas	1. Haze 2. Smoke 3. Dust	1,2,3. Agricultural activity, burning; urban plumes; prescribed burning	1,2. Wildfires 3. Windblown dust	Small increase in utility, industrial coal use;[b,c]
East Mountain	2 North	Impairment outside areas, intermittent in areas	1. Haze 2. Smoke	1. Lake Tahoe, urban plume 2. Prescribed burning	2. Wildfires	Some improvement, with progress toward meeting air quality standards
	7 South	Generally desirable visibility, some impairment out in areas	1. Haze 2. Smoke	1. Agricultural activity, San Joaquin Valley sources	2. Wildfires	
South Coast (W)	6	Generally impaired	1. Haze, smog	1. Los Angeles; other urban plume intrusions; some prescribed burning		
Northern Rockies/Plains	12	Generally desirable visibility Some impairment outside areas	1. Smoke 2. Visible plumes 3. Dust	1,2. Slash, agricultural burning; prescribed burning	1,2. Wildfires 3. Windblown dust; fog	Increased utility coal use;[b] increased industrial coal use;[c] possible decrease in smelter emissions in attaining air quality standards;[e] increased mining energy production activities;[c] associated population growth[c,d]
Colorado	11	Generally desirable visibility	1. Smoke	1. Agricultural burning; saw mills; prescribed burning 2. Urban plumes	1. Wildfires 2. Windblown dust 3. Fog	Significant population growth in CO, UT;[d] associated urban, other development.
"Golden Circle"	9	Some impairment; need to assess noted	1. Haze (intermittent) 2. Visible plumes 3. Discoloration (brown, yellow bands)	1. Power plants; smelters; urban plumes 2. Power plants; miscellaneous small sources	1. Natural haze 2. Wildfires	Possible decrease in smelter impacts from air quality standard attainment[e]
Southern Arizona	11	Generally impaired	1. Regional haze 2. Dust 3. Smoke 4. Discoloration	1. Smelters; urban plumes (Phoenix, Tucson) 2. Agricultural activities; burning 3. Prescribed burning	1. Natural haze 2. Windblown dust	Possible further decrease in smelters emissions to attain air quality standards;[e] major population growth;[d] increased general development
New Mexico/Texas	10	Generally desirable visibility Need to assess noted	1. Haze 2. Dust 3. Smoke	1. Smelters 2. Agricultural activities 3. Prescribed burning	1. Natural haze 2. Windblown dust	Possible decrease in smelter impacts;[e] increased general development[a]
East of 100° Meridian						
New England	6	General desirable visibility	1. Episodic regional haze 2. Visible plumes outside some areas	1. Regional sulfur oxide; fine particle emissions 2. Pulp mills; open dump	1. Fog; Natural haze	Anticipated growth in regional coal use;[c] planned utility growth;[a] oil refinery;[a] significant population growth[d]
Mid-Atlantic	15	Some impairment, need to assess visibility noted	1. Regional haze, more intense in summer 2. Visible plumes 3. Discoloration (grey haze, brown plumes)	1. Regional sulfur oxide; fine particle emissions, urban plumes 2, 3. Miscellaneous industrial sources; prescribed burning	1. Fog; natural haze 2. Wildfire	Some decrease in regional SO_x emissions through air quality Standards, NSPS replacement of older power plants;[b] significant population growth[d]
South Coast (E)	5	Generally desirable visibility	1. Regional haze, more intensive in summer	1. Regional sulfur oxide; fine particle emissions	1. Fog; natural haze 2. Wildfire; prescribed burning	Planned utility growth;[a] increase in utility coal use;[b] significant population growth[d]
Great Lakes	4	Generally desirable visibility	1. Fog 2. Smoke, visible plume	2. Pulp mills (1 area)	1. Fog 2. Wildfire; prescribed burning	Planned Canadian power plant;[a] increased regional utility coal use[b,c]
Midwest	5	Generally desirable visibility	1. Smoke, visible plume 2. Dust	1. Charcoal kiln (1 area)	1. Prescribed burning; wildfires 2. Fugitive dust	Significant increase in utility, industrial coal use, SO_x emissions[b,c]
Noncontiguous U.S.						
Alaska/Hawaii	7	Generally desirable visibility	1. Fog 2. Smoke	2. Agricultural burning[a]	1. Fog 2. Volcanic emissions	Planned power plant siting[a]

[a] Federal Land Manager Workbooks (NPS, 1979; USFS, 1979a; USFWS, 1979).

[b] Utility Emission Projections (ICF, 1979); see Figure 6-18.

[c] Industrial Coal Use Projections (DOE, 1979); see Figure 6-19.

[d] Population Projections (DOC, 1977); see Figure 6-29.

[e] Smelter Emission Projections (Trijonis, 1979); see Figure 6-22.

Source: EPR-450/5-79-008, October 1979, Protecting Visibility: An EPA Report to Congress

Regulatory needs. The Clean Air Act provides regulatory options for local and regional problems associated with visibility and fine particles. For visibility impacts, regional modeling will ultimately be important for controlling existing sources of pollution and preventing new ones. The addition of Sections 165 and 169A to the Clean Air Act in 1977 established a national goal for enhancing and preserving visibility in Class I areas such as certain national parks, monuments, and wilderness areas where visibility is an important resource. Section 169A calls for strategies for visibility protection over a 10- to 15-year period and Section 165 provides a mechanism for achieving the national visibility goal for new source categories. Although initial regulations for visibility protection are limited to single-source impacts, eventually visibility protection regulations may require regional visibility protection strategies.

Major uses of regional models for regulation. Current regulatory programs make use of regional models primarily in three types of analysis: cost/benefit, impact, and control strategy. Benefit analysis establishes the need for regulation by comparing the costs of control with the benefits achieved by it. Regional models may provide the key link between these benefits and costs, particularly for welfare effects (e.g., crop damages). Impact analysis (often called regulatory analysis) determines the effects on the nation's environment, economy, and energy consumption. As these regulatory analyses must reflect broad national perspectives, the kinds of models used for this purpose are less detailed and rigorous than those ultimately required for developing control strategies. Control strategy analysis and development identifies the most promising options for achieving air pollution limitation goals. Because the potential costs to meet a control strategy limit can be very large, great care must be taken that the models supporting each strategy are validated and scientifically credible.

EPA will also need regional models to refine particulate control and visibility air pollution policies. If, in our revisions of the air quality standard for particulate matter, we move to a size-specific standard, the problem of regionally-transported particles might become even more critical than it is now. EPA is currently considering the possibility of revising its total suspended particles standard to include inhalable particles (IP < 15 microns), fine particles (FP < 2.5 microns), sulfates, or other more specific particulate standards during the course of this review process. A decision on the nature of a new standard (or standards) and an accompanying regulatory analysis should be available during FY 1982. Implementation of a revised air quality standard for particulate matter should be implemented between FY 1982 and FY 1985.

In conjunction with the Energy and Environment research program, the modeling work can provide the basis for possible future standards or regulatory actions for visibility and acid deposition. We will be working to develop fine particle/sulfate/visibility relationships and emission/air quality/deposition relationships by conducting field studies to acquire "real-world" data. We expect this work to result in a refinement of regional models that will help to improve benefits analysis and permit regulatory and preliminary strategy analyses in FY 1982.

Air quality model research for regulatory needs. Current regulatory support studies can be grouped into five categories:

- pollutant dispersions at short range (0-100 km);
- complex terrain modeling;
- visibility impairment by plumes;
- updating UNAMAP (User's Network for Applied Modeling of Air Pollution); and
- pollutant dispersion at long range (100-1000 km).

Pollutant dispersion at short range. Studies are being conducted on short-range dispersion of pollutants from simple and multiple sources, released at various heights, over multifarious topography (including water), and under diverse meteorological conditions. For some emission sources, it will be necessary to consider chemical transformations of the primary emitted pollutants into the final product (gaseous or particulate), which may be hazardous to health or biota and cause material damage.

Complex terrain modeling. Resources will be allocated over the next three to five years to obtain field-validated plume and dispersion models in complex terrain. In the first phase, to be conducted in FY 1981 and FY 1982, the effects of plume impaction on a terrain obstacle (such as a hill, mountainside, or ridge) will be studied. In the second phase, to be conducted in FY 1982 and FY 1983, an actual power plant plume dispersion in a valley will be studied. A generic complex terrain plume dispersion model adaptable to various terrain and meteorological situations is expected to be in users guide form by FY 1984.

Visibility impairment by plumes. Power plant exhausts that become plumes that obstruct scenic vistas are an important concern in the western U.S. Several models for predicting plume visibility at great distances from the plume source have been developed and are now being validated. In 1981, ORD plans to complete a series of field studies that will provide the data necessary for model validation. Once tested against these data, the best portions of each of the existing models will be consolidated into a single plume dispersion model for visibility.

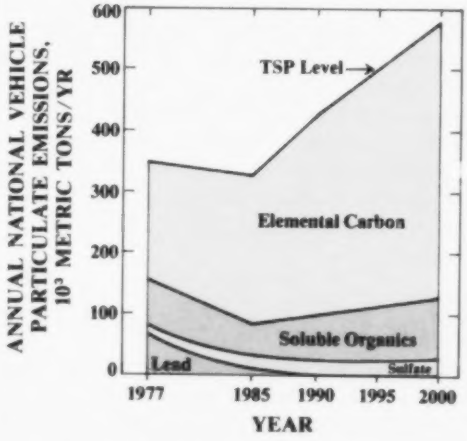
Updating UNAMAP. Periodic updates provide users with a single source for the most recent Air Quality Simulation Models (AQSMs) in computer compatible form. These models, which have been supported by ORD since 1973, provide emission and meteorological data with which to calculate projected air pollutant concentrations.

Four additional models will be incorporated at the next revision. This latest version of UNAMAP, expected to be available in January 1981, will be partitioned into evaluation models, guideline models, proposed guideline models, and models now replaced but still of historical interest. The guideline models will contain revised codes that address previous problems of the models' internal consistency. EPA plans to include the plume blight model in FY 1982 and the complex terrain dispersion model in FY 1984.

Pollutant dispersion at long range. Long-range pollutant dispersion is an important part of regional air pollution problems. In this process, pollutants emitted from tall stacks and from some ground-level sources diffuse to the upper layers of the troposphere and lower stratosphere where they may travel long distances before being returned to the ground. During this relatively long air dwell-time, primary emissions may be transformed into secondary gaseous and particulate products that may fall out hundreds to thousands of kilometers away from the sources.

As long-range pollutants sink into the lower atmosphere, the concentration of inhalable particles (sulfates, nitrates, carbonaceous aerosols) and photo-oxidants (ozone, NO_X, peroxynitrates) may be elevated, posing a health risk to large populations, especially those susceptible to bronchial and pulmonary diseases. The elevated IP concentrations also have an impact on crops, vegetation, and the biosphere in general. From FY 1981 to FY 1985, ORD will study urban- and regional-scale high-concentration pollution episodes in order to establish more definitive cause/effect relationships. By FY 1985, validated predictive models should be able to link emission sources and meteorological conditions to elevated IP concentrations, thereby enabling implementation of rational emission control strategies that will mitigate or prevent health effects.

TOTAL SUSPENDED PARTICULATE COMPOSITION IS PROJECTED, BASED ON BEST DIESEL ESTIMATE WITHOUT PARTICULATE REGULATION



Source: EPA, 1980 Air Quality Criteria for Particulates and SO_X, Draft.

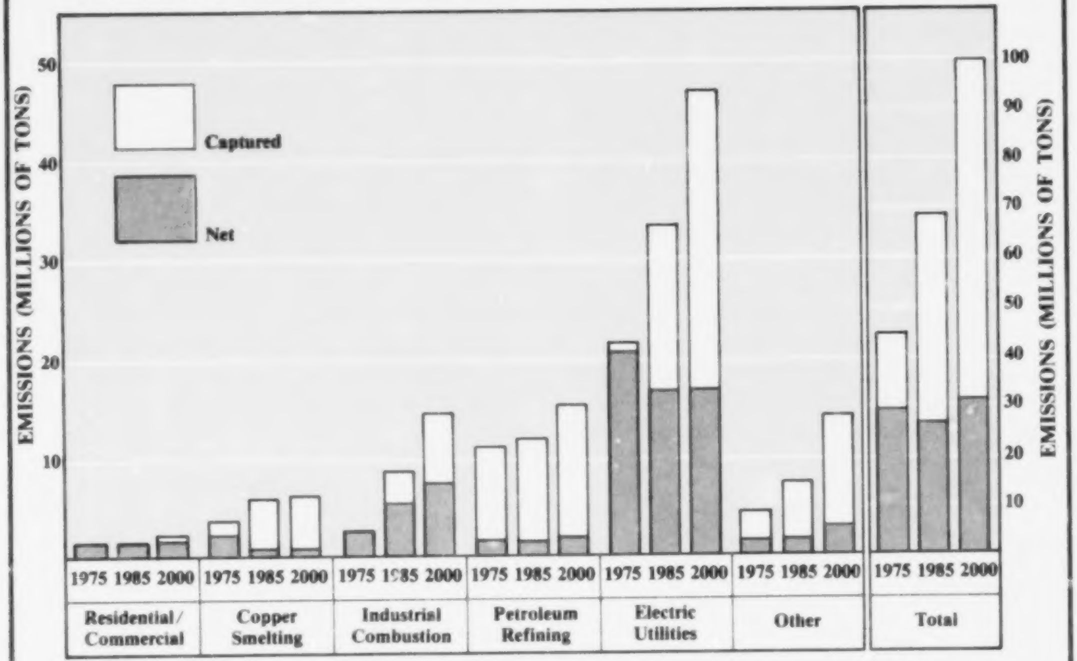
Monitoring, Instrumentation, and Quality Assurance

There has been a continuing need for the evaluation of methods, quality assurance, and field studies associated with EPA air monitoring programs. To meet this need, EPA audits state and local agencies to determine how well their measuring equipment is performing; maintains a standard repository of samples to provide user agencies with ways to trace their standards back to the National Bureau of Standards; and publishes guidelines concerning the best ways to perform physical and chemical analyses of air pollutants.

In addition, the Agency performs research on two other areas: the Inhalable Particulate Network (IPN) and the Exposure Assessment Program.

Inhalable Particulate Network. Since it gradually became evident that particles of different sizes have different health effects—in general, small particles are more dangerous than large ones, since they penetrate deeper into the lung and lodge in the alveoli—the Office of Management and Budget in 1977 directed EPA to establish a national network of air monitoring stations capable of measuring the size of the air

TRENDS IN SULFUR OXIDE EMISSIONS, HIGH GROWTH SCENARIO



Source: U.S. Environmental Protection Agency, 1980a. Environmental Outlook 1980. Office of Research and Development, Washington, D.C.

particles. At the end of the second year of the program, 140 stations had been set up nationwide. Each station now contains equipment capable of measuring the size, as well as the chemical composition of particles—sulfates, nitrates, and metals. Measurements are taken every eight days, and resulting data will be used to increase understanding of the effects of geography, meteorology, emissions from industry and motor vehicles, and other factors on the quality of the air we breathe. We expect the network to grow to a total of 180 stations by 1981.

Exposure Assessment Program. EPA's knowledge of human exposure to pollutants in the air we breathe, the water we drink, and the food we eat has been recognized as one of the weakest links in its efforts to protect the environment. Recent advances in technology, however, have made it possible to measure human exposure to many chemicals encountered during normal daily activities. In 1977, EPA recognized the need for development and evaluation of instruments that could be used to measure directly individual exposure to air pollutants. An interagency agreement with the National Bureau of Standards was set up to develop a respirable particulate monitor and to evaluate several commercially available particulate monitors and NO_2 samplers. We have also supported development of personal monitors that could detect many organic chemicals such as chloroform and benzene at ambient levels. As these and other monitors have been developed, ORD's Office of Monitoring and Technical Support has deployed them in a series of pilot studies designed to test the monitors under field conditions. Three major pilot studies ongoing in FY 1981 include the Total Exposure Assessment Methodology (TEAM) study in New Jersey, a study of energy-related pollutants (respirable particulates and SO_2) in Canada, and a study of CO exposures in several U.S. cities.

Welfare Effects of Sulfur Dioxide

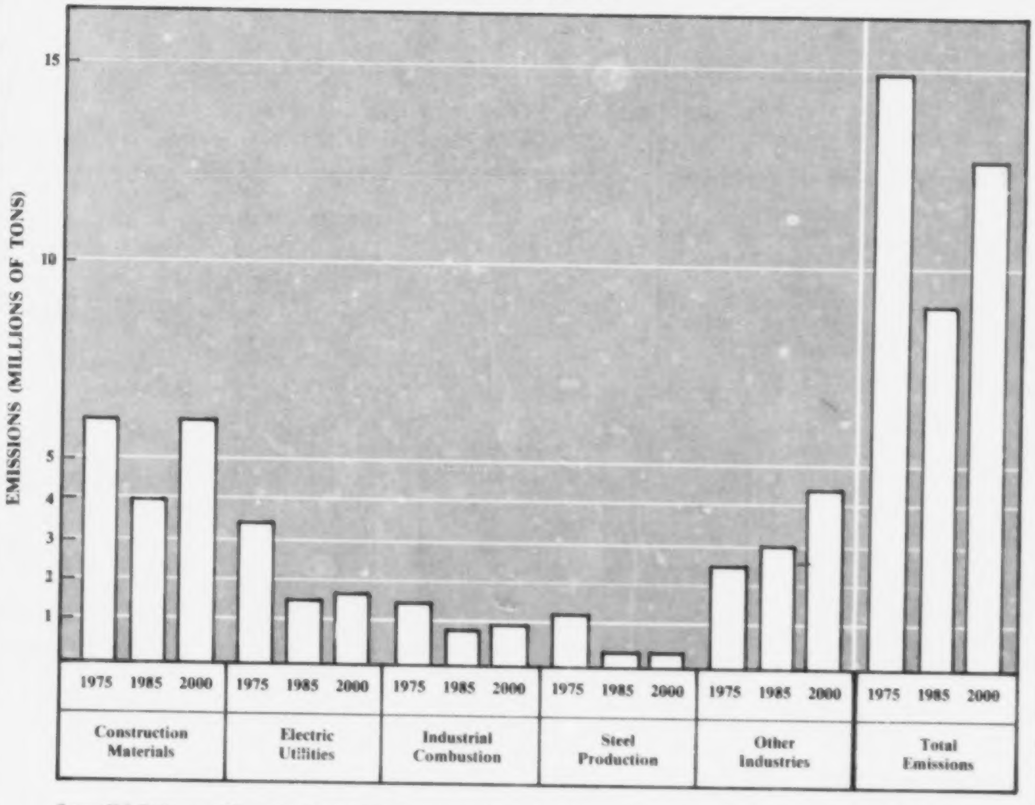
Research within the welfare effects program focuses on the development of dose/response thresholds for SO_2 impacts on vegetation. Thorough examination of this dose/response concept, which correlates the duration and concentration of pollutants (dose) with effects (response), will provide the basis for the development of scientifically defensible air quality criteria. Specific research objectives are to determine: (1) the possible reduction of SO_2 thresholds by the presence of other gaseous air pollutants; (2) the relationship between dose/response thresholds and environmental factors such as water availability; and (3) the importance of genetically induced variation in plant reproduction, survival, and tolerance of SO_2. Outputs from this research will assist in evaluating the effects of pollutant mixtures (SO_2, NO_2, and O_3) as EPA establishes secondary air quality standards for SO_2, and considering environmental factors in the establishment of localized standards or air pollution control strategies.

The scientific assessment program provides the vital link that translates research data into summary statements about the nature or degree of health hazard associated with exposure to gases and particulate pollutants. The typical program output, an assessment or criteria document, establishes the health impact basis for EPA's regulatory approach.

In 1980 and 1981, the assessment program is concentrating on updating the SO_x and particulate matter criteria document. With the completion of this update in late 1981, the Agency will reexamine the existing SO_x/inhalable particle standard.

In late 1981 and early 1982, the assessment program will initiate a program to update the lead criteria document so that in 1983 the Agency will have the necessary scientific data base to reconsider the existing ambient lead standard.

TRENDS IN NET PARTICULATE EMISSIONS, BY SOURCE
HIGH GROWTH SCENARIO
1975, 1985, 2000



Source: U.S. Environmental Protection Agency, 1980a. Environmental Outlook 1980. Office of Research and Development, Washington, D.C.

EMERGING PROBLEMS AND ASSOCIATED RESEARCH NEEDS

In order to determine the impacts of particulate matter and sulfur oxide emission on human health, ecology, and welfare, the ambient concentrations of these materials must be measured. But, since limited data are available on particle size and chemical composition, impacts will be difficult to project. Thus, the following trends are not intended as predictions of the future; rather, they are intended to provide a basis for the research strategies required for establishing programs and controls to mitigate or eliminate potential negative impacts of sulfur oxide and particulate matter.

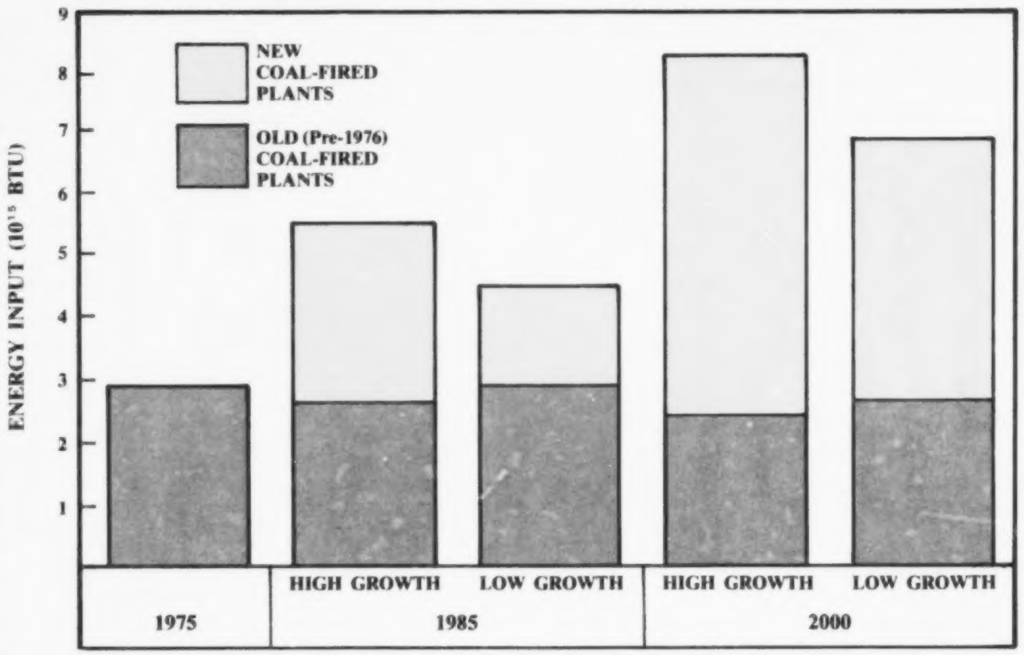
Future Trends and Factors Affecting Them

Sulfur Oxide Emission Trends. The generation of SO_x is expected to increase from 45 million tons in 1975 to nearly 99 million tons in 2000. The installation of control devices to meet regulations, however, would result in approximately a 10 to 20% decrease in projected net emissions by 1985; then continued economic growth would begin to cause net emissions to increase gradually. By 2000, net emissions under high-growth conditions are expected to range about 6% higher or lower than the 1975 level.

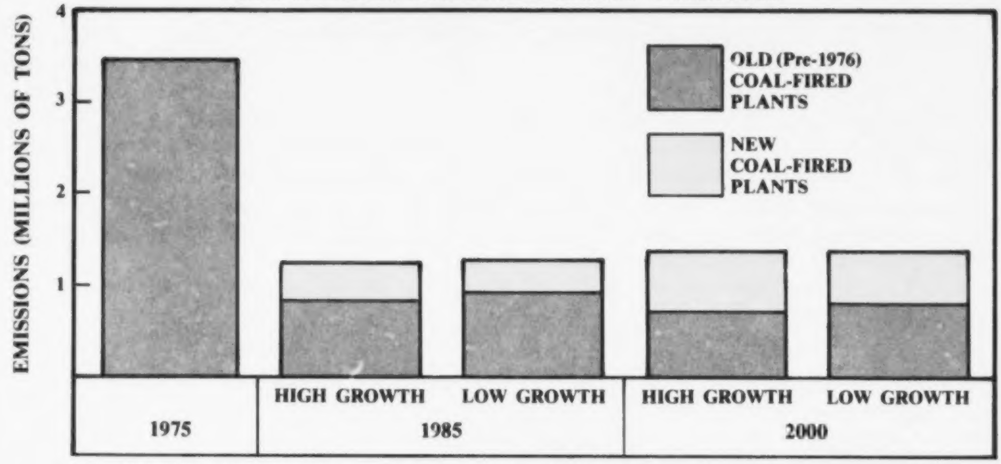
In 1975, fossil fuel combustion in electric utilities and industrial plants produced about 75% of the SO_x emissions. Since coal use in electric utilities, the major coal-consuming sector, is expected to more than double by 2000, contributions to the SO_x burden by coal will increase over 1975 levels.

Particulate Matter (PM) Emission Trends. In 1985, controlled particulate emissions are projected to be at their lowest during the 1975-2000 period—approximately 40% below 1975 levels. However, because of the absence of more stringent emission controls, economic growth and increasing fossil fuel use after 1985 are expected to reverse the downward trend; PM emissions will approach 85% of 1975 levels by 2000. The construction materials industry (which includes

TRENDS IN COAL USE BY NEW COAL-FIRED ELECTRIC UTILITIES



Source: U.S. Environmental Protection Agency, 1980a. Environmental Outlook 1980. Office of Research and Development, Washington, D.C.



TRENDS IN NET PARTICULATE EMISSIONS FROM COAL-FIRED ELECTRIC UTILITIES

Source: U.S. Environmental Protection Agency, 1980a. Environmental Outlook 1980, Office of Research and Development, Washington, D.C.

glass, cement, sand and gravel, and similar sources) is the major direct source of particulate emissions, accounting for approximately 40% of total net emissions. This is the only industrial source for which particulate emissions in 2000 are projected to exceed 1975 levels.

Regional Trends. Some regional trends differ substantially from the national trends because of differences in the composition of regional industrial sources, economic growth patterns, and state emissions requirements. One such trend is found in the Great Lakes Region (Federal Region V), where, between 1975 and 2000, net particulate emissions are projected to decline approximately 50% under high-growth conditions, as compared with an average decline nationwide of 15%. Total net particulate emissions in the Great Lakes Region accounted for more than any other region in 1975; by 2000, that region's contribution is projected to decline from 30% to less than 15% of the national total. This will occur because of a reduction in emissions from the region's coal-fired utilities. Nevertheless, Federal Region V is expected to remain one of the nation's largest sources of particulate emissions.

Other differences in regional trends can be found in the Middle Atlantic Region (Federal Region III), the Southeast Region (Federal Region IV), and the South Central Region (Federal Region VI).

Implications for future research. ORD's Office of Strategic Assessment is currently investigating projected and potential socioeconomic trends for implications for environmental impacts. The following three examples suggest current shifts in trends that may require detailed investigation to determine the significance of the problem and the potential solutions. Some research is already under way in each of these areas.

Growth in the Sunbelt. The general growth, development, and projected increase in particulate, SO_X and NO_X emissions in the sunbelt implies the need for additional research on the potential for acid deposition, visibility degradation, and long-range transport. Extensive research is planned for the Ohio River valley, and particular attention will be paid to semi-arid areas such as the Southwest. The transformation and fate processes governing air pollutants in the Southwest are significant because the ecology in that area may be more sensitive to pollutant effects, and the dry climate may increase the potential for long-range transport to surrounding pristine areas.

Wood Burning. In some parts of the country the trend toward wood burning is increasing as fossil fuels become more expensive. In the Northeast, more than 20% of all residences are heated with wood; nationally, sales of wood stoves have increased approximately 25% per year since 1973. The DOE has set a national goal of tripling current wood use by the turn of the century.

With increased wood use, however, come concerns about air pollution, including deterioration of both ambient and indoor air quality. Wood stoves are unable to achieve complete combustion, and emissions include both gaseous and particulate pollution. Wood burning is also one of the most significant sources of polycyclic organics (POM), which are suspected of being hazardous. In addition, many of the volatile hydrocarbons from wood burning are suspected carcinogens and precursors of photochemical smog. To deal with these pollutants, New Hampshire and Vermont have already restricted wood boiler conversions in valleys susceptible to particulate haze, while Vail, Colorado, is attempting to control the problem by limiting the amount of wood burning in residences.

Alternatives to wood, however, such as coal or peat, produce greater emissions of TSP, SO_X, and potentially hazardous pollutants than wood. Research is currently under way at both DOE and EPA to assess the potential environmental problems and to provide wood stove design improvements to increase energy efficiency and reduce pollutant emissions. EPA researchers also are attempting to identify types of wood that have the least pollution potential.

GASES AND PARTICLES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Health Effects	Complete studies and publish final reports on acute and chronic effects in animals of exposures to "coarse-mode" (2-15 μm) and "fine-mode" (< 2.5 μm) airborne particles					▲
	Complete studies and publish final reports on acute and chronic effects in animals of exposure to airborne particles in combination with pollutant gases				▲	
	Complete studies and publish final reports on the acute effects (physiologic, biochemical, and immunologic) in humans from exposures to sulfate and nitrate aerosol pollutants		▲			
	Complete and publish reports on development of techniques and equipment for more sensitive and more reliable indicators of acute effects in humans from exposures to airborne pollutants			▲		
	Complete ongoing studies and publish summary reports of health effects on populations exposed to airborne sulfur oxides and particles			▲		
Monitoring Systems and Quality Assurance	Operate 160 (including 10 to 15 percent special site) IP network stations throughout FY 1981	□				
	Expand IP network to 200 stations (including 10 to 15 percent special sites) and conduct necessary methods development	□				
	Characterize the distribution of ambient particulate matter at eight locations using the wide-range ambient aerosol classifier	▲				
	Assess, develop, and characterize schemes for extracting and fractionating organics from ambient particulates	▲				

▲ Final report, manual or user's guide; △ Interim report or manual; ● Prototype equipment and report; ★ Interim or final criteria formulations; ○ Final protocol; ■ Continuing effort; □ Other, self-explanatory

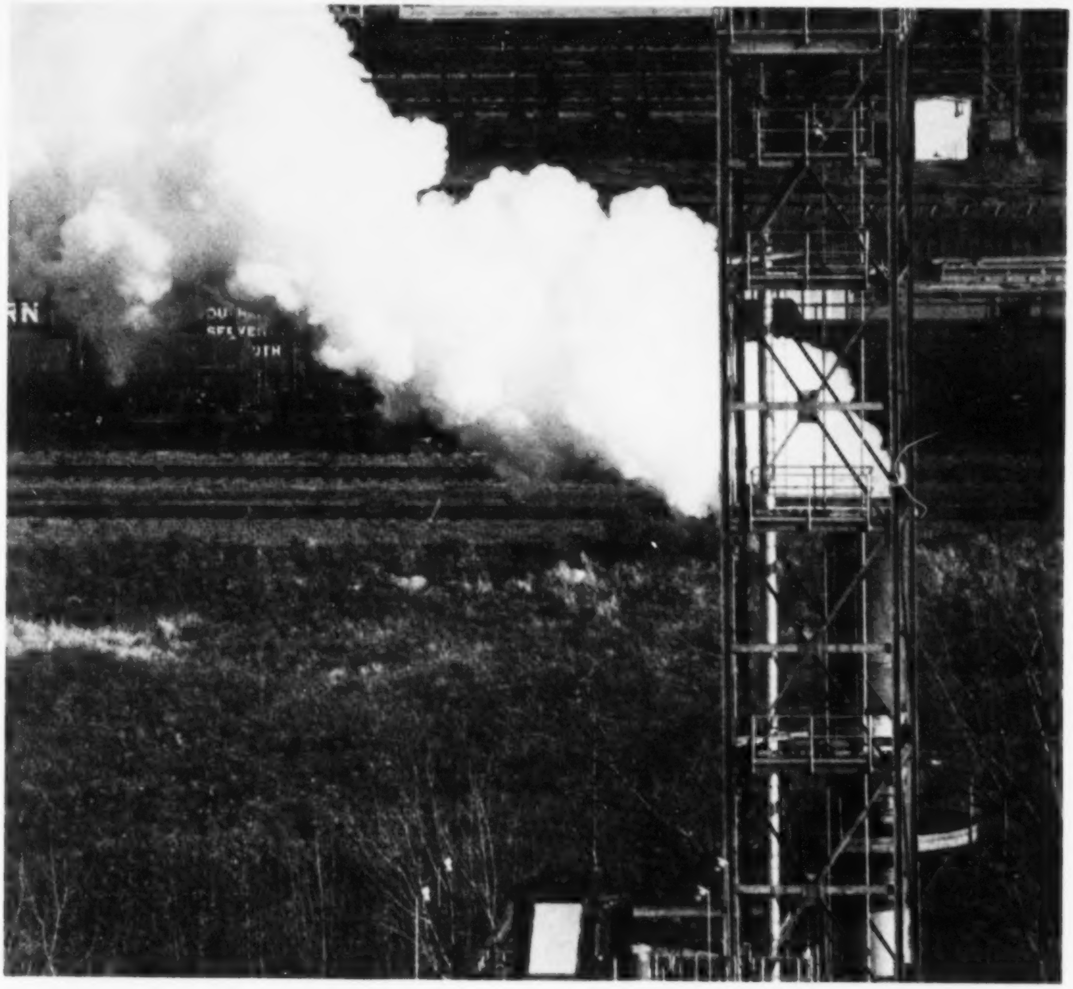
GASES AND PARTICLES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Systems and Quality Assurance	Evaluate, improve, and optimize current air pollution methodology and monitoring techniques	▲				■
	Develop, evaluate, improve, and optimize nontraditional air pollution methodology and monitoring techniques	▲				■
	Conduct performance audits for all IP network samples, validate IP data, and conduct evaluations of methods for measuring constituents in the IP fraction	▲				■
	Provide Quality Assurance (QA) and technical support to state and local agencies and regional offices, required to implement the QA requirements of 40 CFR 58 State and Local Air Monitoring Systems/National Air Monitoring Systems (SLAMS/NAMS)	▲				■
	Develop new items and maintain a current repository of Quality Control (QC) reference samples and materials, conduct semiannual performance audits for sulfur dioxide and nitrogen dioxide, sulfur dioxide, nitrates, lead, carbon monoxide, Methods 5, 6, 7, and analysis for BTU and sulfur content of coal	□				
	Conduct unanticipated and special audits of selected ambient/source monitoring projects. Conduct semiannual audits and performance surveys of compressed gas vendors	□				
	Develop and distribute six methods on ambient air for Volume II of the QA Handbook and three methods on stationary sources for Volume III of the QA Handbook	▲				
	Develop and test performance specifications and prepare QA procedures applicable to source emission continuous monitors	▲				
	Provide QA and conduct 20 to 25 performance audits for continuous source emission monitors	□				■
	Provide quality assurance support for OAQPS, HERL, and ESRL studies	□				■
	Develop, evaluate, and validate methodology for use in gathering ambient and emission data and review and process reference and equivalent method applications	▲				■
	Verification of certified reference materials and EPA contractors organic analysis	▲				■
	Support the implementation of the Agency's mandatory QA Program. Support Air Quality Monitoring Systems (AQMS) in implementing the mandatory QA Program	□				■
	Maintain and periodically update list of acceptable measurement methods for regulated noncriteria pollutants in ambient air	□				■

GASES AND PARTICLES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81 82 83 84 85
Air Quality Modeling and Model Evaluation	Evaluate pollutant dispersion from point, line, and area sources in complex terrain	△ △ △ △ ▲
	Develop urban-scale model for support of fine particle standards and regulations	△ △ △ △ ▲
	Determine emission factors of fine particles for various industrial sources	△ △ ▲
	Study source apportionment of fine particles from emission sources and analyze collected particles	△ △ ▲
	Develop aerosol submodule for urban- and regional-scale fine particle models	△ △ ▲
Visibility	Develop and evaluate plume blight model	▲
Ecological and Crop Yield Effects of Gases and Particles	Examine dose-response relationships, thresholds, crop and forest impacts of SO_2, NO_2, and O_3	△ △ △ △ ▲
	Study solar attenuation, crop yield, and climatic effects of man-made aerosols	△ △ ▲
Scientific Assessments		
SO_x PM Criteria Document	Complete criteria update by obtaining CASAC (Clean Air Scientific Advisory Committee)	▲
Lead Criteria Document	Update lead criteria document	▲

OXIDANTS



When pollutants such as gases, particles, and aerosols are released into the atmosphere, they often react with one another or with oxidants already in the air to form new compounds. These reaction products, possessing altogether new chemical characteristics, can, in turn, affect human health and the environment in vastly different ways than would the compounds in their original form.

These atmospheric reactions are a major concern of the Oxidant Research Committee (ORC), particularly those involving ozone, nitrogen oxides, and volatile organic compounds (VOC) that both contribute to and are created by the in-air chemical transformation of pollutants. Reaction products of these oxidants include:

- ozone, nitrogen dioxide, peroxyacyl nitrates, and nitric acid;
- aldehydes, such as formaldehyde, acetaldehyde, acrolein, and benzaldehyde;
- nitrous acid and hydrogen peroxide; and
- organic nitrates, ketones, and organic acids.

Secondary reactions involving these oxidants may also result in the formation of sulfuric acid aerosols, organic aerosols, and particulate nitrates.

These reaction products cover such a broad chemical spectrum that many are of interest to other research committees. For example, the Gases and Particle Research Committee is studying the primary emission and secondary formation of finely-divided aerosols and coarser particles. The Hazardous Air Pollutants Research Committee is interested in specific VOC compounds, particularly those primary VOC that are emitted directly by a source, rather than those resulting from atmospheric processes. The Mobile Source Research Committee is concerned with VOC and NO_x emissions from vehicles.

Current Regulatory Responsibility

One of the major goals of the Clean Air Act (CAA), as amended in 1977, is to protect and enhance the quality of the nation's air in order to promote the public health and welfare. Six CAA provisions pertain to the control of oxidants. These are:

1. National Ambient Air Quality Standards
2. State Implementation Plans
3. New Source Performance Standards
4. Prevention of Significant Deterioration
5. Visibility Protection
6. Motor Vehicle Emission Standards (see Chapter 6).

National Ambient Air Quality Standards (NAAQS). Under Sections 108 and 109 of the CAA, *primary* NAAQS to protect public health and *secondary* NAAQS to protect public welfare may be set for pollutants that are found in the ambient air and that originate from stationary or mobile sources. Responsibility for the attainment of standards is given to the states, which are required to specify emission limitations and other restrictions through State Implementation Plans (SIPs). EPA's responsibility is to promulgate NAAQS, to develop and review air quality criteria and control techniques, to evaluate alternatives, and to provide guidance for the development of SIPs.

Major oxidant research committee interest in support of NAAQS focuses on ozone and nitrogen dioxide (NO_2). Of particular concern are those areas which have not yet attained the initial NAAQS for ozone and NO_2 in the three- to five-year span set forth in the CAA for the attainment of the primary standard. Included in the 1977 Amendments are special provisions for these areas, requiring that standards be obtained by December 1982; an extension for ozone, however, is available to December 1987.

The 1977 Amendments also require that all the NAAQS be reviewed and revised, if necessary, by December 1980 and every five years thereafter. The NAAQS for ozone was the first to be reviewed and in February, 1979 was revised from 0.08 ppm to 0.12 ppm, maximum expected 1-hour average concentration, not to be exceeded more than one day per year. Preparation of a revised criteria document by ORD's Environmental Criteria and Assessment Office is scheduled to begin in FY 1982 with proposal of a revised standard, if necessary, scheduled for June 1984. All research that will be used in the review and revision of the ozone standard will need to be complete and peer-reviewed by early 1983.

As a result of the 1970 CAA amendments, an NAAQS for hydrocarbons was promulgated as a means of attaining and maintaining the 1971 oxidant standard. To meet the 5-year review requirement of the 1977 CAA amendments, the criteria for hydrocarbons have recently been reviewed, resulting in recommendations that the hydrocarbon NAAQS be rescinded and that the relationship between precursor hydrocarbons and ozone and other photochemical oxidants be treated in the future in the ozone criteria document. Appropriate regulatory action on the hydrocarbon NAAQS is in progress at this writing.

The 1977 Amendments also direct EPA to determine the need for a short-term (one- to three-hour) NO_2 standard. This review was conducted, but was subsequently incorporated into the full criteria review for NO_x. However, the review of the present long-term NO_2 standard (100 $\mu g/m^3$, annual average) has been delayed, and, as a consequence, any revision of this standard is not expected until late 1981. Since the criteria document for this review is virtually complete, research is already under way for the next NO_2 review cycle, and is programmed to be available by the end of 1984.

Secondary NAAQS for sulfates and nitrates may be necessary in support of planned acid rain and visibility impairment regulations. These regulations should be initiated by mid-1981, with proposal of standards, if appropriate, to come by late 1982. Supporting this effort, the Oxidant Research Committee will provide technical information about NO_x control technology as well as NO_x transport and transformation.

While some research will be devoted to determining the effects on the public health and welfare of other nitrogen oxides and photochemical oxidants, no regulatory plans for establishing NAAQS for these pollutants are expected over the next five years.

State Implementation Plans (SIPs). EPA's Office of Air Quality Planning and Standards will provide guidance to states in preparing SIPs for controlling

VOC emissions. Research in the form of VOC control strategy guidelines will support this guidance. Also required over the next five years will be research into the air chemistry aspects of the ozone problem, particularly to assist those areas that have not met initial NAAQS deadlines, and that have qualified for a 1987 extension. 1977 CAA amendments require of these areas a "second-phase" SIP demonstration of attainment, to be submitted by July of 1982. If this demonstration still indicates problems with attaining the standard by 1987, a demonstration of strategy for attaining the standards based on photochemical dispersion modeling must be submitted by states to EPA as expeditiously as practicable. Research over the next several years will support this effort.

New Source Performance Standards (NSPS). Section 111 of the CAA allows new source performance standards to be set for new or modified air pollution sources that emit criteria pollutants or even, in some cases, non-criteria pollutants. These standards must reflect the best available control technology that has been demonstrated for a given emissions source category, while at the same time taking into account costs and other factors. Thus, their setting requires the use of the most up-to-date technical information about available control technology, including removal efficiencies, economic considerations, energy penalties, and any environmental impacts not manifest as air pollution.

Presently, NSPS exist for a number of VOC and NO_x sources, a number of additional NSPS are in preparation, and current standards are being reviewed periodically. The committee's research supports the technical data requirements for these facets of the NSPS process.

Prevention of Significant Deterioration (PSD). Sections 160-169 of the CAA establish national requirements for prevention of significant deterioration of air quality from new source impacts. The Act provides varying degrees of protection for three types of land areas. Class I areas are generally pristine regions, such as national parks and wilderness areas. Class II areas are those thought ideal to accommodate normal, well-managed industrial growth, and Class III areas are those appropriate for a larger amount of development.

Currently, under these sections of the Act, no permits for proposed major new pollution sources can be approved until air quality modeling determines whether or not levels of sulfur oxides or particulate matter in the potentially affected PSD areas would increase. Yet to be established by the EPA, as set forth in the Act, are similar PSD regulatory programs for the other criteria pollutants, including ozone and NO_2. Regulations for these criteria pollutants will be proposed by August 1981, at which time additional research will be required in support of the regulatory effort.

The Act also requires a case-by-case determination of best available control technology (BACT) for those emission source categories subject to PSD review. Continued research will be needed for making informed and defensible BACT determinations.

Visibility protection. Both Section 165 (PSD) and Section 169A of the Act provide for the protection of visibility in Class I areas, with Section 169A specifying the enhancement and preservation of visibility in these areas as a national goal. Currently, one hundred fifty-six Class I areas — most of which are located in the western United States — are enjoying visibility protection.

Section 169A also calls for the development of long-term visibility protection strategies, which, over a ten- to fifteen-year period, should aid in the achievement of national visibility goals. To this end, visibility protection regulations for existing and new pollution sources should be promulgated in 1980. Initially these regulations are expected to deal principally with single source impacts; eventually, however, regional visibility protection regulations may be developed.

OXIDANTS RESEARCH

In support of the CAA and its 1977 amendments, the Oxidant Research Committee will oversee the following research:

- preparation of criteria documents for ozone and nitrogen dioxide NAAQS;
- development and validation of models to support SIPs for ozone and nitrogen dioxide;
- development of control technologies for ozone and nitrogen dioxide precursors, volatile organic compounds, and nitrogen oxides, both in support of SIPs and the NSPS program;
- investigations into the significant deterioration of air quality by ozone and nitrogen dioxide;
- development of effective NO_x control technology to eliminate the contribution of nitrogen dioxide to "plume blight" visibility problems; and
- long-range research on a variety of oxidants and products of atmospheric photochemical reactions.

Research in support of the development of NAAQS criteria and standards will study health effects, welfare effects and relevant atmospheric processes. Health effects research will focus primarily on ozone and nitrogen dioxide, and will involve clinical, as well as toxicological and epidemiological studies. For ozone, clinical studies will generally be for short-term exposures since the ozone standard is predicated on a one-hour exposure to ozone concentrations. Nitrogen dioxide toxicological studies, on the other hand, will involve short- and long-term studies to support the NO_2 standard. Toxicological research for both oxidants will make use of animal studies to determine better the toxicological effects of varying exposures and dosages. Epidemiological studies will make possible overall health assessments by analyzing large population groups and their exposure to entire arrays of pollutants.

Welfare effects research to support development of criteria will focus on evaluations of economic losses from crop damage, visibility impairment, and materials damage. Once determined and quantified, crop loss information may be used to support a secondary ambient air standard for ozone based on decreases in yields. Already established is a multiyear program to better determine losses due to several criteria pollutants; to augment this program, however, more dose/response measurements must be made and more accurate methods for establishing economic loss must be developed.

Atmospheric processes research in support of the NAAQS effort will involve study of chemical transformation processes, pollutant transport, and the contribution of natural sources to pollution concentrations. The information that is developed will support requirements for criteria documents and ambient air standards.

Following development of NAAQS criteria and standards, EPA research will focus on solving problems which impede attainment. Areas to be studied are:

- monitoring and measurement methods;
- pollutant characterization;
- pollutant transport;
- chemical and physical transformations;
- pollutant deposition; and
- development of control technology for oxidant precursors and other compounds.

Research on monitoring will evaluate new models of field instrumentation and develop quality assurance procedures. Characterization, transport, transformation, and deposition research will help to determine whether emission sources or atmospheric processes are the major contributors to air pollution and the overall degradation of environmental quality. This effort will be facilitated by the development of new and improved mathematical models capable of quantitatively relating emission sources to air quality. It is also expected that these tools will assist states in the preparation of SIPs.

The development of control technology for oxidant precursors will help to bring about the achievement of ozone standards in many non-attainment areas of the country. Similarly, development of nitrogen oxide controls for new and existing sources will help achieve the health-related ambient air standard for nitrogen dioxide. NO_2 control will also result in the partial abatement of acid rain and visibility problems, while NO_x control will help cut down on crop losses by decreasing ozone formation in rural areas.

Health Effects of Ozone and Nitrogen Dioxide

Research into the health effects of exposures to ozone or NO_2 will have the highest priority during FY 1981-1983.

Toxicological studies. Currently, insufficient toxicological data exists to determine whether a long-term exposure standard for ozone concentrations is needed to supplement the present short-term standard. Program research will provide this data. Studies during FY 1981-1983 will expose rats of various ages to ozone concentrations of between 0.08 and 0.25 ppm, 8 hours a day, 7 days a week for periods of 1 to 12 weeks. A variety of biological responses including pulmonary function, change in lung behavior, and biochemical response will be studied following acute and subchronic exposures to ozone concentrations below 1 ppm. Biomathematical models will then be developed to predict ozone pulmonary dose/response patterns in man and animals. Final results will be available in FY 1984.

Studies of the effects of long-term exposure to ambient concentrations of nitrogen dioxide will also start in FY 1981. Mice exposed to 0.2 ppm of NO_2, with peak exposures to 0.8 ppm, will be tested for lung morphology and pulmonary functions which will then be used as response parameters. In related studies, rats exposed to nitrogen dioxide concentrations below 1 ppm and below 5 ppm will be investigated for changes in lung tissue, immune response, red blood cell function, and biochemical parameters. FY 1981 results will cover the effects of NO_2 on animals deficient in glucose-6-phosphate dehydrogenase.

Similar acute and subchronic exposure studies will also be conducted for combinations of ozone and nitrogen dioxide. Effects will be measured for lung behavior, immune, and biochemical responses.

Clinical studies. Clinical studies on exposure to ozone will be conducted in FY 1981 at the University of North Carolina School of Medicine. Ozone study results available in FY 1981 will include the further documentation of reduced pulmonary function in healthy young white males exposed for two-hour periods to ozone concentrations between 0.12 ppm (the current standard) and 0.40 ppm. Another study to be reported in FY 1981 will document the combined effects of intermittent exercise, elevated temperature and humidity, and exposure to mid-range concentrations of ozone. Initial study subjects will be healthy white males; a later expanded study population will also include healthy black males and patients with chronic obstructive pulmonary disease. Both studies will investigate pulmonary functions, cardiovascular functions and immune biochemical changes.

New NO_2 exposure studies planned to begin in FY 1982 include exposures to NO_2 alone and in combination with ozone. FY 1981 NO_2 health effects research will therefore concentrate on the development of the physiological methodologies needed to conduct the 1982 research effort. Available in FY 1981 will be results from a study of normal and sensitive subjects exposed to low NO_2.

Epidemiological studies. FY 1981 will see continued analyses of existing health data in order to assess the factors that determine respiratory disease. Data bases to be analyzed include mortality figures from major metropolitan areas, chronic disease prevalence in adults, and lower respiratory disease prevalence in children.

Funds made available from our energy research program will support epidemiological studies in the Los Angeles basin so that in subsequent years comparisons can be made with the Gulf Coast study results. The Los Angeles study in FY 1981 will focus on asthmatics and other sensitive subjects. Overall study results will be reported in FY 1985.

Welfare Effects of Ozone, Other Oxidants, and Sulfur Dioxide

Major research focus in FY 1981 will be the continuation of the five Regional Crop Loss Assessment projects which are part of the program of the National Crop Loss Assessment Network Plan (NCLAN). The aim of the research is to develop dose/yield relationships for major agronomic crops in order to determine productivity. Crops will be exposed to O_3 and SO_2 in the field under conditions that simulate as nearly as possible the natural environment. Preliminary assessments of the effects will be available in FY 1982. Further reports comparing season-to-season variabilities in dose/yield results for the crops will be reported in FY 1983. Dose-response functions and economic loss estimates will be made in the project report in FY 1984.

Research determining the biogenic emission of hydrocarbons, the effects of PAN on growth and yield of crops, the effects of water stress on plant ozone sensitivity, and the effects of NO_2 on plants is also being carried out.

In conjunction with this effort, crop exposure modeling techniques will be refined, along with the methods used for making economic estimations. We will also develop assessment methods and air quality monitoring and modeling techniques capable of simulating the growing season effects of oxidants on major U.S. crop areas.

Two sulfur dioxide research projects will be conducted to meet the needs of the Gas and Particle Research Committee; the projects will address the interactions between ozone and sulfur dioxide and between sulfur dioxide and nitrogen dioxide.

Transport, Transformations, and Removal Processes for Ozone, Nitrogen Dioxide, and Related Pollutants

Committee transport and fate research focuses on the development, evaluation, and validation of urban- and regional-scale air quality simulation models for oxidants. Air quality simulation models for chemical kinetics will be developed, improved, and validated in smog chamber studies. Meteorological analysis techniques will also be developed for the simulation models. To ensure the general applicability of these models, emission inventories of volatile organic hydrocarbons and nitrogen oxides will first be acquired, then used in urban and rural field studies that will cover a large range of environmental parameters. Chemical experiments to support the transport and fate modeling program will determine: (1) which volatile organic compounds do not contribute to oxidant formation, and (2) whether natural hydrocarbons such as isoprene and monoterpenes can contribute to oxidant formation in rural areas.

Six transport and fate models will be under development or evaluation in FY 1981:

- EPA Empirical Kinetic Modeling Approach (EKMA)(does not require an emission inventory);
- EPA photochemical box model (PBM);
- Urban Air Shed Model;
- Lagrangian model;
- Livermore Regional Air Quality Model (LIRAQ); and
- Northeast Regional Oxidant Model (a regional model).

During FY 1981, the EKMA model will be tested against available data from St. Louis, Houston, Tulsa, and Philadelphia; the PBM model will be tested against St. Louis and Northeast data; and the four urban models will be validated with ambient air monitoring results obtained in St. Louis.

The status of the chemical kinetic portions of all these models is currently being evaluated; in FY 1981 an improved validated mechanism for aromatic hydrocarbon chemistry should be available. By the end of FY 1982, verification results will be available on the application of a regional oxidant model to the northeastern United States, and by FY 1983 a report should be available on the application of this model to areawide control strategies in the northeast corridor.

Before urban- and regional-scale models can be fully developed, however, a number of questions about low reactivity organics and the roles of natural organic emissions in oxidant formation must be resolved. It is not known, for example, whether the slow reaction speed of low-reactivity organics emitted from industrial sources, vehicles, and possibly from hydrocarbon seepage in natural gas- and oil-bearing lands precludes their being significant contributors to atmospheric ozone buildup. If research bears this out, then they may be exempt from SIP control requirements. Smog chamber test results and test protocols for measuring reactivities for a selected group of these compounds will be available in FY 1981.

It is also not known whether natural organic emissions contribute extensively to the atmospheric ozone load burden, though it is thought that these emissions may be significant enough to warrant their inclusion in regional-scale emission inventories. If borne out by research, this could mean that natural emissions from a large forested area upwind of a city might, for example, contribute the initial organics or ozone load to air that subsequently moves into an urban area. Results of a program that measures natural hydrocarbon emissions from a forested area in eastern North Carolina to either support or contradict this hypothesis will be available in FY 1981. A final report summarizing available field results and modeling of these results will be available by FY 1983.

Once we know more about low-reactivity organics and the role played by natural emissions in ozone formation, urban- and regional-scale models can be tested. Two sites—Houston and Atlanta—have been chosen for testing the urban-scale air quality simulation model for ozone. Both cities are ideal in terms of size, pollution sources, and meteorological conditions. Further research is needed, however, to complete Houston emission inventories and to gather Atlanta air quality measurements. The regional-scale ozone model which is being developed for the Northeast should be tested in the South, most ideally along the Gulf Coast, where significant population growth, industrial expansion, and utility conversions to coal or lignite are all projected. Meteorological conditions in the region are also conducive to ozone formation.

Control Technologies for Volatile Organic Compounds (VOC)

VOC control research focuses on the evaluation of VOC emission sources and the development of techniques to determine the efficiency of carbon adsorption systems, hooding systems, and flares in the removal or destruction of VOC. A study to evaluate VOC emissions during sludge treatment and disposal will be initiated in FY 1981 and completed early in FY 1983. Study results documenting the long-term performance of several carbon adsorption units in full-scale industrial applications will be available in FY 1981; overall performance evaluations will be provided in FY 1982. A prototype measurement system to evaluate VOC capture efficiencies of hooding systems used in the graphic arts, rubber processing, plastic processing, and metal coatings industries will be developed in FY 1982.

An interim report available in FY 1981 and a final report in FY 1982 will document the efficiency of flares in the destruction of VOC. FY 1981 interim and FY 1982 final reports will also document the type and frequency of leaks of VOC from equipment at a large number of petrochemical process units. Research will also result in the publication of a series of performance manuals for the control of VOC. These will be developed and issued during FY 1982, and will be used both to develop New Source Performance Standards and to document emission factors.

Over the longer term (FY 1981-1984), low-NO_X burner technology in industrial and utility boilers will be evaluated and regulatory support will be provided for utility and industrial boiler reviews (FY 1983-1984).

RESEARCH FOR EMERGING PROBLEMS

An environmental problem can emerge as an outgrowth of a new technology or, far more simply and insidiously, because our ability to discern it has improved. Our recent capability for measuring environmental pollutants in extremely low concentrations—parts per billion or per trillion—has, for example, resulted in the "emergence" of new environmental issues, though, in fact, they had existed all along.

Improved discernment capabilities, new technologies, and an ever-evolving environmental picture are the precursors of the eight emerging problems now being considered by the Oxidant Research Committee. These are:

- volatile photochemical reaction products other than ozone and NO_2;
- atmospheric formaldehyde;
- economic losses of ornamentals, flowers and shrubs, grazing lands, and forests;
- uncertainties and inaccuracies in emission inventories;
- hydrocarbons that contribute to VOC and ozone;
- ozone formation and consumption and VOC removal in the troposphere;
- oxidants downwind of coal conversion and shale oil facilities; and
- oxidant model development to meet PSD regulations.

Volatile photochemical reaction products other than ozone and nitrogen dioxide. A number of volatile inorganic and organic chemicals that are formed as pollutants in the atmosphere photochemically react with one another. Substances formed in these photochemical reactions include peroxyacetyl nitrate, nitric acid, hydrogen peroxide, formaldehyde, acrolein, and formic acid. Such reactions are particularly common in Los Angeles where spectrometric tests to measure atmospheric substances show individual compounds occurring at 5 to 20% of the concentration of ozone with the sum of these compounds equaling one-half of the city's total ozone concentration.

While is it known that many of these chemicals, particularly formaldehyde, cause pulmonary responses and other irritations, far more data are needed to assess accurately the spectrum of effects from single compounds and from combinations of these compounds with ozone. Animal toxicology studies that make use of smog chambers to generate those compounds would be the appropriate initial approach for determining these effects. This would enable a comparison of the effects of the entire pollutant mixture with the effects of ozone alone, or of ozone in combination with nitrogen dioxide. Such animal studies require substantial planning prior to their initiation. Thus, studies to be begun in FY 1983 or FY 1984 should be planned during FY 1982 or FY 1983.

Formaldehyde. Formaldehyde, a key initiating chemical of ozone formation, is also a suspected carcinogen, an eye irritant, and a respiratory irritant. While atmospheric formaldehyde can be emitted from vehicles and industrial sources, it is largely created through chemical reactions in the atmosphere. During daylight hours, it is formed as hydrocarbons and higher molecular weight aldehydes react. It is also destroyed, however, during daylight hours as it reacts with nitrogen oxides or is acted on by sunlight. As a consequence, formaldehyde formed early in the day will be largely destroyed before sundown, while formaldehyde formed late in the day will remain stable throughout the hours of darkness. In a study using samples of Los Angeles ambient air and auto exhausts, peak concentrations occurred only after several hours of exposure of the samples to sunlight, with initial concentrations being considerably lower—15 to 20% of the peak concentration in the auto exhaust samples and 25% in the ambient air samples. Results of these and other studies demonstrate that high photochemical activity during daylight hours is largely responsible for observed urban formaldehyde concentrations. Far less is known, however, about formaldehyde formation under less intense photochemical conditions.

Research will be conducted in FY 1982 through FY 1984 on formaldehyde concentrations in the ambient air during both daylight and nighttime hours and under a variety of seasonal conditions. Smog chambers will be used as part of this research. Studies will also compare formaldehyde concentrations levels in homes, office buildings, vehicles, and other locations to determine whether ambient air or sources within the various confined spaces are the major contributors to indoor concentrations. This research will be coordinated with the Hazardous Air Pollution Committee.

Additional studies of formaldehyde's potential for eye irritation or pulmonary responses are also needed. However, the FY 1983 deadline for the completion of ozone health studies may mean that, because of resource limitations, no substantial health research on formaldehyde will be feasible until the research that supports criteria and standards for ozone is brought to a finish. Once begun, the formaldehyde studies would extend through FY 1985.

Economic losses involving ornamentals, grazing lands, and forests. The national crop loss assessment network (NCLAN) program, currently under way, involves study of the economic losses posed by oxidants to agriculturally important crops. Not included in the FY 1980-1984 program, however, are studies of yield reductions or other effects on plants such as ornamentals within cities, grazing land grasses, and forests. These studies would likely be longer-term and would produce more difficult to quantify economic results than the current study. Still, such a program is important and FY 1981-1983 research results will enable us to decide if it should be instituted.

Uncertainties and inaccuracies in emission inventories. Adequate urban- and regional-scale emission inventories are needed to determine whether air quality standards are being attained. Also, to make use of air quality simulation models, finer emission measurements are required. Unfortunately, such inventories are today marked by inconsistent quality, particularly those for hydrocarbons and NO_X, and attempts to improve them are complicated by a variety of factors. Some major sources, such as vehicles, for example, emit both VOC and NO_X, while others may emit one or the other but not both. Sources may be widely dispersed, or in close proximity. They may be found in rural areas, as is the case with NO_X emitted from faraway tall stacks, or in urban areas, where more hydrocarbons are concentrated. Still further complicating the improvement of emission inventories is the extensive influence weather patterns can have on emission-mixing rates and the ability of precursor emissions to generate ozone and nitrogen dioxide.

Research beginning in FY 1981 will grapple with these complications in an attempt to improve emission inventories and air quality simulation models. As a result, better forecasting of air quality trends will be possible.

Hydrocarbons that contribute to VOC and ozone. Excess atmospheric concentrations of hydrocarbons, particularly paraffinic hydrocarbons, have been identified at gas and oil fields. These emissions may, in turn, increase local ozone concentrations or may contribute pollution to air masses passing through that have originated in distant urban or industrial areas. In a study to identify the contributions made by various sources to the excessive concentrations of atmospheric hydrocarbons in the Los Angeles area, measurements have been made at several sites in California's south coast air basin, a gas and oil production area, as well as at other major hydrocarbon sources. Results of the study indicated that geogenic natural gas—methane, ethane, propane, butanes, pentanes, and some higher-molecular-weight paraffins—emanating from these sources constituted, on the average, 15% of the non-methane hydrocarbons in Los Angeles county and 12% of the non-methane hydrocarbons sixty miles east of downtown Los Angeles. The presence of geogenic natural gas has also been reported in the Jones State Forest, north of Houston, Texas, as well as near Jetmore, Kansas.

If, in fact, the relationship between geogenic gas seepage from gas and oil field operations and elevated concentrations of atmospheric hydrocarbons can be rigorously established, then, considering the number and widespread nature of such operations, their overall effects on the nation's atmosphere could be substantial. Research planned to better determine this relationship will require the measurement of ground-level amounts of VOC, NO_X, and ozone found in non-urban areas where gas and oil production activities take place, and subsequent comparison of those amounts with the pollutant levels found in non-urban areas with no nearby gas or oil fields. Meteorological parameters should also be measured so that back-trajectory analyses can be carried out. The data acquired in this research will then be used to design smog chamber experiments for simulation of ozone formation conditions. Preliminary measurements could be initiated in FY 1981-1982.

Ozone formation and consumption and VOC removal in the troposphere. Today, several models are purported to be capable of predicting background levels of ozone in the free troposphere. However, their use often results in widely disparate conclusions, owing primarily to a lack of consistency in the atmospheric data on which they are based. The Fishman and Crutzen model, for example, predicts net photochemical ozone *production* at middle latitudes in the northern hemisphere, while the Chameides and Stedman model predicts net ozone *destruction*. Yet each of these net amounts depends on the concentration of NO_X in the free troposphere, for which few measurements exist. The models also depend upon accurate deposition rates for nitric acid, hydrogen peroxide, and other products, all areas where existing measurements are inadequate. Refining the models will thus require these measurements to be taken, a task that is expected to continue well into the 1980s.

The need for the refinement of these models has further importance because of their ability to provide estimates of tropospheric concentrations of OH radicals. Concentrations of OH radicals are important because the radicals react with compounds such as methylchloroform, hydrogen-containing fluorinated molecules, perchloroethylene, and other low-reactivity chemicals, removing them before they can reach the stratosphere and deplete the ozone layer which protects the earth from the sun's rays. These persistent chemicals also absorb infrared energy and can thus influence changes in climate. Valid models capable of estimating OH concentrations and precise monitoring of OH to support the models are therefore significant to any research involving the study of climate, including studies on the depletion of stratospheric ozone.

Oxidants downwind of coal conversion and shale oil facilities. Tomorrow's coal conversion and shale oil facilities will have the potential for emitting volatile organic substances and nitrogen oxides. Volatile organic compounds could, for example, be emitted from coal conversion processes that pretreat gases, from cooling towers and from leaks in valves, flanges, and other fittings. Nitrogen oxides will be found in the site's steam boiler exhaust. These substances, as part of the facility's pollution plume, can then be swept downwind to react with one another and with other agents in the ambient air to form oxidants.

To anticipate better what environmental consequences may result from the proliferation of these facilities, field studies will be required at currently operating plants that are large enough to produce significant plumes. Ideally, facilities used for study will be sufficiently isolated from other sources so that accurate measurements of pollutant contributions can be made. Measurements commencing before a facility begins operation will be necessary to define background concentrations of ozone and its precursors. It is anticipated that the planning and design of such studies should begin two years prior to start-up of a facility.

Oxidant models to meet PSD regulations. Currently, PSD regulations only exist for sulfur dioxide and total suspended particulates (TSP); regulations must be issued for all the other criteria pollutants as well. By statute, a single approach was required for SO_2 and TSP regulation, but not required for the other criteria pollutants. Modeling will probably be used to determine the most feasible approach for developing oxidant PSD regulations, which will require the assessment of current model capabilities and the validation of models that might be of potential use. A decision to proceed will be made in FY 1981.

FUTURE TRENDS

Two anticipated trends merit discussion in some detail because of their significant potential to affect air quality in the 1980s and 1990s. The first relates to the impacts on regional air quality that will accompany the high rates of population and industrial growth anticipated for the southern and southwestern U.S. The second future trend to be discussed involves the expected increase in diesel-powered vehicle use and the impacts of the altered emission patterns that this increase will bring about.

Population and industrial growth and air quality. Since 1950, the southeastern and south central portions of the country, EPA Regions IV and VI respectively, have undergone rapid increases in population, growth of manufacture and industry, and development of natural resources. These trends are expected to continue, with chemical and petroleum industries growing and vehicular traffic and electricity generation on the rise. As a result, it is highly probable that photochemical oxidant problems in these Regions will worsen significantly.

Over the period 1970-1978, all 13 states in EPA Regions IV and VI exceeded the national population growth rate, with eight states growing at a rate 1.5 times or more the national rate. Of these, Florida, New Mexico, and Texas grew the fastest. Over this same period, the Regions have also increased their share of the nation's industrial output from one third to one half, with mining, smelting, pulp mills, petrochemical, fertilizer, and cement manufacture providing most of this industrial growth.

As a result, air quality in both Regions has suffered, and is expected to continue to suffer. Although the total amount of hydrocarbon emissions for the nation is expected to decrease, emissions in the southern states are not expected to decrease as fast as the national rate. In some areas, such as Region VI, they are even expected to increase, with high anticipated growth rates in the paints and other chemical products industries chiefly responsible. The high growth rate in vehicle miles driven that will accompany the projected disproportionate population growth rate will also mean a slowing in hydrocarbon decreases in the regions, as will the high ratio of trucks to cars in these areas, the former being less stringently controlled. Another major hydrocarbon source will be the petroleum refining and storage industry, already contributing nearly 20 percent of net emissions in Region VI and expected to continue to do so until about 2000.

Marked increases in oxides of nitrogen are also predicted for Regions IV and VI, with gross and net emissions of NO_x projected to grow disproportionately in the southeastern states, compared to the projected increases for the nation. Primarily responsible for this area's increases will be expanded coal-fired electric power generation.

Another major factor in determining both Regions' future air quality will be the regional climate, significantly and complexly influenced by the states' proximity to the Gulf of Mexico. The Gulf, for example, commonly produces thermal layering in the atmosphere which keeps turbulent mixing heights low and encourages the formation of oxidants. This layering also complicates the study of turbulent diffusion processes. On the positive side, moderate winds off the Gulf increase the frequency with which clean air is mixed with stagnant air in the southeast and south central states. This is not, however, the case in the southern Appalachian region, where the potential for stagnation reaches 40 days per year, the nation's highest outside the western states.

The amount of sunlight in the South, another important aspect of climate that is also a major influence in the formation of oxidants, varies considerably across the southern states. Only moderate sunshine, for example, is experienced by the Gulf and southern Appalachian states, owing to intrusions of turbid and cloudy tropical maritime air. The south central states, on the other hand, with their clear skies and their low latitudes, get one-and-a-half times as much sunshine as the rest of the country.

The Regions are also characterized by high relative humidity; however, little is known about the effect such humidity has on ambient air oxidant formation.

Today there is significant evidence that the Regions' growth has had an impact on air quality. Of the 79 air quality control regions either wholly or partly in EPA Regions IV and VI, 22 currently exceed the national ambient air quality standard of 0.12 ppm for ozone. Highest oxidant levels are found in the area circumscribed by Houston, Galveston (0.26 ppm), southeast Texas, and southern Louisiana (0.19 ppm), an area expected to see significant growth in petroleum refining and petrochemical production by the year 2000. High oxidant levels are also found in the central Kentucky-central Tennessee area, as well as elsewhere in Tennessee and in a number of areas in South Carolina, Georgia, and Alabama. Problems in many of these already impacted areas are expected to worsen, with anticipated large increases in oxides of nitrogen from coal combustion, along with continued population and industrial growth. These factors will conspire to make more difficult the attainment of ambient air standards for oxidants.

EPA has undertaken extensive studies of photochemical oxidant formation in the Gulf Coast area. This and other studies of the region would be well augmented by the testing of more urban-scale air quality simulation models. In light of expected growth patterns, Houston and Atlanta would be excellent test sites. Testing a regional model in the Gulf Coast and adjacent areas would also be especially useful.

Impacts of diesel emissions on oxidant formation. Current estimates indicate that 25 percent of light-duty passenger vehicles will be diesel powered by 1995, and that consumption of diesel fuel will grow 5 percent annually through the year 2000. While diesel automobiles consume 25 percent less fuel than gasoline engines of similar power and emit fewer hydrocarbons, they can, however, result in the generation of more NO_X. How these alterations in vehicular emissions will affect oxidant levels is unclear.

What is clear is that the replacement of gasoline vehicles with diesel light-duty highway vehicles would significantly reduce hydrocarbon emissions from these sources, owing to the small amounts of hydrocarbons they produce—0.41 grams per mile for those diesels to be produced in the 1980s and 1990s according to EPA estimates. This is drastically lower than the 8.27 grams per mile produced by EPA's 1975 composite gasoline-powered light-duty vehicle and significantly lower than the 1.83 grams per mile estimated for gasoline-powered light-duty vehicles in 1995. With light-duty vehicles expected to account for 78% of total motor vehicular hydrocarbon emissions in 1995, a reduction from 1.83 grams to 0.41 grams per mile could reduce hydrocarbon emissions from mobile sources by approximately 60%. As a consequence, a reduction in hydrocarbon-related oxidant problems is anticipated.

NO_X-related oxidant problems may be exacerbated, however, with EPA's best estimate for light-duty diesel vehicles being 1.6 grams per mile. While this meets the current standard of 2 grams per mile, it is in significant excess of the Clean Air Act requirement of 1 gram per mile. Two-year waivers to the present NO_X standard have been recently granted by the EPA to three auto makers—General Motors, Daimlerbenz (Mercedes), and Volvo.

To further complicate the diesel NO_X problem, particulate emissions increase when NO_X controls used in gasoline engines are adapted to diesel engines. The particulates involved include a wide variety of organic material, including polycyclic aromatic hydrocarbons, which are known to be carcinogenic in test animals. Resolution of the NO_X question will thus depend on the development of new NO_X controls, and in the interim on the regulatory balance struck by EPA between NO_X and particulate control.

OXIDANTS RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Health Effects of Ozone and Nitrogen Dioxide	Study short NO_2 exposures of asthmatics to assess changes in pulmonary functions	■				
	Produce replication of NO_x effects using bronocho constrictors	■				
	Study threshold of ozone effect on pulmonary function of human subjects at levels near existing standards	■				
	Study ozone effects on human subjects under thermal and exercise stress	▲	▲			
	Determine effects of oxidant air pollutants on human resistance to viral infections in respiratory tract		▲	■		
	Determine oxidant effects on lung mechanics and respiratory function	▲				
	Study effects of ozone and nitrogen dioxide on cardiovascular effects in animals	▲ ▲	▲	▲		
	Study exposures of animals to nitrogen dioxide at levels simulating ambient concentrations with use of a variety of animal models	▲	▲			
	Determine lung injury caused by ozone to animals near current ozone standard	▲	▲		■	
	Develop detailed protocol for Los Angeles asthma study	▲	■			
Welfare Effects of Ozone and Nitrogen Dioxide	Update Stanford Research Institute's model for estimating damage to agriculture from air pollutants	■				
	Study effects of photochemical oxidants on a western coniferous forest ecosystem	■				
	Determine dose-response data for yield response of important crops to ozone and ozone and sulfur dioxide in combination	▲	▲	▲	▲	■
	Assess economic losses to agricultural crops due to ozone and sulfur dioxide		▲	▲	▲	■
Transport, Transformation, and Removal of Ozone, Nitrogen Dioxide, and Related Pollutants	Report on the evaluation of chemical, kinetic, and mechanistic data for photochemical oxidant modeling	■				
	Provide air quality simulation modelers with validated mechanism for aromatic hydrocarbons in photochemical models	■				
	Report on smog chamber results to develop test protocols for photochemical reactivity	■				
	Report on reactivity of low molecular-weight volatile organic compounds		■			
	Report on accuracy of and validation of EKMA model using air quality data from eastern and western urban areas	▲	▲		▲	■

▲ Final report, manual or user's guide; △ Interim report or manual; ● Prototype equipment and report;
★ Interim or final criteria formulations; ○ Final protocol; ■ Continuing effort; □ Other, self-explanatory

OXIDANTS RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Transport, Transformation and Removal of Ozone, Nitrogen Dioxide, and Related Pollutants	Prepare report and evaluation validation studies on several urban-scale air quality simulation models for oxidants using St. Louis (RAPS) air quality data	▲	▲ ■			
	Prepare final report on Houston Air Quality Program		■			
	Report on formation and transport of oxidants in southeastern United States		▲			■
	Report on validation of Northeast Regional Oxidant Model (NEROS)		■			
	Apply NEROS for control strategy assessments in northeastern corridor			■		
	Conduct symposium on natural hydrocarbons	■				
	Determine biogenic hydrocarbon contribution to ambient air in selected areas	▲ ▲	▲	▲▲	■	
	Assess importance of natural and stratospheric sources of ozone and its precursors as compared to anthropogenic sources					■
Control Technology for Volatile Organic Hydrocarbons and Nitrogen Oxides	Conduct prototype utility boiler low-NO_x burner testing		■			
	Conduct 30-day comprehensive emission test of field application of low-NO_x burner design to an industrial boiler		■			
	Determine effect of maintenance on reducing fugitive VOC emissions from the synthetic organic chemicals manufacturing industry		■			
	Conduct first comprehensive test of low-NO_x burner at a utility boiler test site			■		
	Develop fugitive VOC emission measurement and control technology			■		
	Measure VOC emissions from secondary sources in the chemical manufacturing industry				■	
	Develop improved VOC capture systems for diffuse sources			■		
	Develop means to control fugitive VOC from organic chemical industry			■		
	Develop technique to measure captive efficiency in hooding systems				■	
	Determine efficiency of flares in burning organic chemicals				■	
	Evaluate catalytic incineration (oxidation) of VOC emissions (coil coating and auto painting)	■				
	Evaluate performance of carbon adsorption in the control of VOC		■			
	Evaluate VOC pollution control demonstration plant in textile printing operation			■		

OXIDANTS RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Control Technology for Volatile Organic Hydrocarbons and Nitrogen Oxides	Establish regulatory support for utility boiler NSPS review				■	
	Develop low-cost retrofit technology for NO_x to use on utility boilers at western sites				■	
	Determine performance of low-NO_x burner over 18-month performance on utility boilers (wall- and tangentially-fired)		▲		▲	■
	Study performance of low NO_x burners at two industrial boiler sites		▲	▲	▲	■
	Establish regulatory support for industrial boiler NSPS review					■
Monitoring, Quality Assurance, and Technical Support	Develop overhead air quality monitoring in support of Eastern Corridor Oxidant Study	■				
	Conduct comparison testing of remote vs. airborne in-situ sensors				△	▲
	Develop technical assistance document for NMOC monitoring		■			
	Develop standard reference UV photometers for distribution to regions states		(demo) □			▲
Criteria Documents	Prepare air quality criteria document for nitrogen oxides	▲	■			▲■
	Revise air quality criteria document for ozone			▲		■

MOBILE SOURCES

VOLKSWAGEN
RABBIT
EPA966

ORD's mobile sources research program is built upon several key projections of future motor vehicle and fuel use. Among the most important projections are the following:

- Light-duty, diesel-powered passenger vehicles will account for at least 25% of total U.S. automobile sales by 1995. This increase in diesel-powered vehicles will result in an increase in particulate emissions from transportation sources.
- Total emissions of carbon monoxide, hydrocarbons, and nitrogen oxides from motor vehicles will decline between 1975 and 1990 due to emission controls. Beyond 1990, emissions will begin to increase due to increasing vehicle miles traveled.
- Transportation sources will continue to be dependent on petroleum-based fuels (including fuels from oil shale and coal). Petroleum fuels are projected to satisfy at least 95% of the energy needs for transportation in 2000. Synthetic fuels (from oil shale and coal) will become an increasingly important source of energy, accounting for as much as 20% of U.S. oil production in 2000.

These projections raise pressing current and emerging problems that the mobile sources research program attempts to address within the context of its five-year outlook. Future problems are also implicated by these (and other) projections.

CURRENT PROBLEMS

Diesel emissions. EPA will use research on diesel emissions in considering what revisions, if any, might be made to recently established diesel particulate standards. Current standards are based primarily on EPA's judgment as to what available control technologies can achieve. Data on the health effects of diesel emissions will allow EPA to determine if the standards are sufficiently stringent to protect public health without imposing unreasonable and unneeded burdens on manufacturers and users of motor vehicles.

While providing a fuel-efficient alternative to the gasoline engine, a diesel-powered engine of comparable size emits 30 to 100 times more particles. The particles and compounds adsorbed onto these emissions are suspected carcinogens because the combustion of any organic matter will produce a complex mixture of polycyclic aromatic hydrocarbons and other compounds, a number of which are carcinogenic. The problem is to identify the biologically active elements in diesel exhaust, estimate the carcinogenic potency of the exhaust, estimate the likely levels of human exposure, and ultimately assess the cancer risk in humans posed by increased use of diesel engines.

The Mobile Sources Research Committee's plan for addressing the problem contains the following major components:

- Direct exposure of animals to diesel exhaust via inhalation to induce tumors. Results are scheduled for the first quarter of 1981.
- Exposure of animals to diesel soot and to coke oven emissions, roofing tar emissions, and cigarette smoke condensate. Since the last three substances are known human carcinogens, by comparing diesel soot with these substances we expect to be able to estimate the soot's potency. Results will be available in 1981 and 1983 for comparative skin painting, in 1983 for comparative intratracheal instillation, and in 1981 for comparative intraperitoneal injection.
- Characterization of the components of diesel soot to isolate and identify the biologically active components, leading to possible control techniques. These studies are under way and results will be emerging over the next two years.
- Development of techniques to use short-term *in vitro* tests, such as the Ames test, to identify the biologically active components in diesel exhaust. This work will continue over the next four years. Major reports will be available in 1981 on the relative cancer potency of diesel exhaust as measured by *in vitro* bioassays. Recommendations as to how *in vitro* tests might be used for cancer-based regulation of engine systems and fuel and fuel additives will be available in 1983.

The importance of the program extends beyond the immediate problem of assessing the risk of increased use of diesels. It represents a pioneering effort in the evaluation of complex carcinogenic mixtures for the purpose of supporting cancer risk assessments.

While the program leads to an assessment of the cancer risk of diesel emissions in terms of known human carcinogens, before this risk can be evaluated accurate estimates of population exposure to diesel emissions, in specific, and all automotive pollutants, in general, must be obtained. This brings us to the second major current problem.

Exposure assessment. Does a reading from a fixed monitor give us an accurate picture of the levels of automotive pollutants to which people are exposed? The answer to this question is critical in determining whether mobile source emission standards for carbon monoxide, hydrocarbons, and nitrogen oxides adequately protect public health. (Currently the standards are based on judgments of technological and economic feasibility.) This issue takes on added significance in light of the projection that total mobile source emissions are likely to increase after 1990.

To respond to this problem, ORD is conducting a major study to determine actual human exposures to carbon monoxide (CO). Carbon monoxide will be studied first because it is emitted almost exclusively from mobile sources, it is relatively easy to measure, and concentrations vary greatly as a function of location. The project will make use of personal monitors to measure the concentrations of CO subjects are exposed to at different times and locations. Human activity profiles will be developed for selected cities to determine where and when the overall population would be exposed to CO.

To assess how levels of other motor vehicle pollutants vary as functions of time and location, similar field experiments using personal monitors would have to be performed. The human activity profiles developed in the CO study should provide a tool for estimating exposures to other mobile source pollutants, including diesel particulates.

Health effects of carbon monoxide. The health effects of exposures to CO at or near the ambient standard (40 mg/m^3 maximum one-hour concentration) need to be established more definitively. ORD is responding to this need with clinical and animal toxicologic studies. The clinical studies will (1) assess the validity of a method for relating ambient CO levels in air to actual CO levels bound to the blood, and (2) report on the effects of exposing young and middle-aged normal people and cardiovascular patients to various levels of CO and CO/ozone mixtures. The toxicologic study will look for teratologic effects caused by CO exposure.

ORD is pursuing these specific areas because results of other studies indicate that further investigation might reveal adverse CO effects. These adverse effects need to be addressed in evaluating the carbon monoxide ambient air standard and the automotive emission level that such a standard implies. (See also the health effects work on nitrogen oxides in Chapter 5.)

EMERGING PROBLEMS

Short-term toxicity tests. Future trends in engine and fuel use for vehicles will require the development of tests that can be used to determine whether different engine systems, fuels, and fuel additives pose an unreasonable risk to health. ORD would like to determine which engineering and fuel modifications can minimize biologic activity as a function of many engine and fuel parameters. Short-term tests for carcinogenicity, mutagenicity, and teratogenicity are necessary to quickly and inexpensively establish such relationships.

In vivo and *in vitro* tests are being developed that can be used for characterization of biologic activity and for quickly screening emissions for further testing. Successful short-term tests would enable quantitative estimation of risks without having to go to larger and more expensive tests. The following test methods are being developed:

- Mouse skin tests—skin painting tests that screen for early tumors—are under development as a reliable predictor of later skin cancer development. Development of the lung adenoma model would enable production of lung adenomas, a non-cancerous tumor, to be used reliably as a cancer predictor.
- A rat liver test is being developed to establish a reliable relationship between abnormalities in the regeneration of the liver after part of it is cut away and later emergence of liver cancers.
- Sister chromatid exchange is a test that measures the exchange of genetic material from one chromosome to another. Induction of such exchanges in animal bone marrow cells after whole animal exposure to a substance is evidence of mutagenic potential. Research is needed to determine whether a reliable relationship can be established between increased sister chromatid exchange and later development of cancer.
- Hemoglobin adduct tests are assays that use a metabolite of a material to measure the amount of it attached to hemoglobin in the blood. This development is an attempt to establish a reliable relationship between such adducts and the total exposure of an individual to the substance.
- Microbial mutagenesis and oncogenic (tumorogenic) transformation tests compose the *in vitro* systems that ORD is developing. The goal here is to establish a reliable quantitative relationship between test results and cancer development.

Characterization of complex mobile source emissions. This problem area concerns identification and measurement of emissions (and components of emissions) from a variety of engines burning different fuels under varying operating conditions. Research will strive to answer questions regarding optimal control of mutagenic substances in diesel emissions and likely environmental effects of combustion of synthetic fuels. Emphasis will also be placed on characterizing the emissions from heavy-duty diesel engines.

A problem to be overcome in this area is the difficulty of sampling gaseous emissions from all types of engines. A method must be developed that does not change the biological characteristics of the exhaust either by generating active artifacts or by suppressing biological activity.

FUTURE PROBLEMS

Recent assessments of the commercialization of different engine types do not project major penetration of the gas turbine engine until the late 1980s or emergence of the electric or hybrid vehicle as a viable alternative until the 1990s. EPA must be in a position to evaluate the environmental and health effects of the introduction of such new engine technologies in a timely fashion. The characterization, measurement, and bioanalytical tools now under development should allow EPA to make these important evaluations. We expect that the measurement and assay systems, once shown to be reliable and accurate, will be available for testing a broad range of engines, fuels, and fuel additives.

The overall contribution of ethanol and methanol (used to make "gasohol") to future fuel supplies is currently uncertain. At present, gasohol accounts for one-tenth of one percent of gasoline consumed for highway use, but by 1985 this proportion could rise to four-tenths of one percent. If alcohol fuels become a significant portion of our energy supply, EPA must be able to evaluate their unique combustion products. An increase in aldehyde emissions would be likely to accompany growth in gasohol use. Since the health effects data base on aldehydes is sparse, we would expect to initiate studies to examine the health effects of exposures to higher levels of aldehydes.

MOBILE SOURCES RESEARCH PLAN

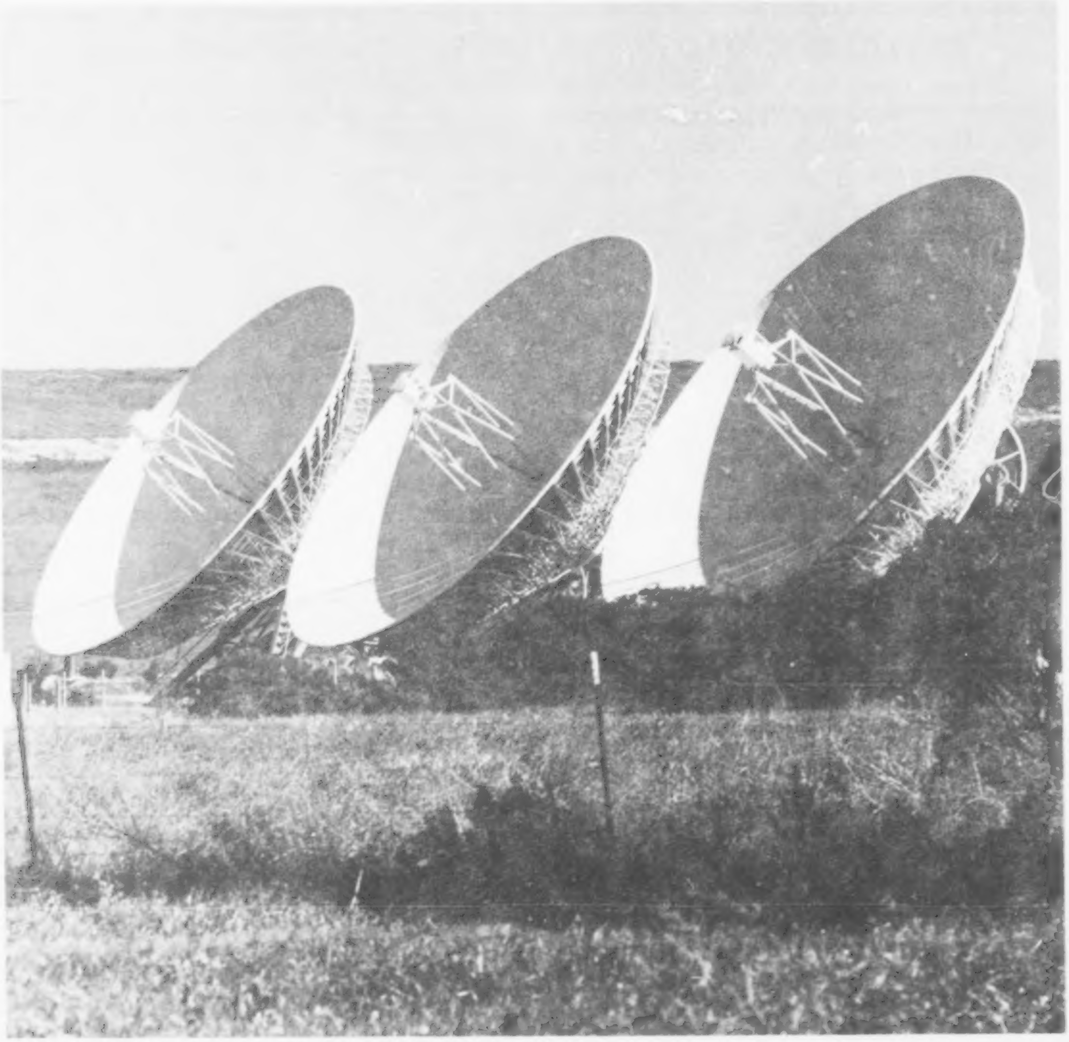
PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Exposure Assessment	Complete pilot study of individual exposures to carbon monoxide using personal air quality monitors. Publish journal article and EPA technical report	▲				
	Complete study of activity patterns of individuals as related to exposure to air pollutants. Publish journal article	△				
	Publish final report on winter 1980-1981 CO exposure monitoring in four cities	▲				
	Register fuels and fuel additives as specified in Clean Air Act					■
	Provide analytical support for HERL-RTP in mobile-source related air pollution studies					■
	Begin first year of field monitoring to determine CO exposure in major urban areas. Publish work plan	△				
	Complete first full year of monitoring CO exposure in major urban area. Publish progress report. Begin similar effort in second area		△			
	Complete study in first urban area. Submit journal article for publication			△		
	Begin study of exposure to other mobile-source-related pollutants, such as NO_X or diesel particulates				△	
	Complete CO studies. Publish journal article					△
	Complete initial NO_X diesel particulate studies. Publish journal article					△

▲ *Final report, manual or user's guide;* △ *Interim report or manual;* ● *Prototype equipment and report;*
★ *Interim or final criteria formulations;* ○ *Final protocol;* ■ *Continuing effort;* □ *Other, self-explanatory*

MOBILE SOURCES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Mobile Source Characterization	Characterize the emissions of motor vehicles using synthetically-derived fuels		▲		▲	
	Determine the impact of varying driving conditions such as speed, temperature, and acceleration on the emissions of environmentally important unregulated pollutants	▲		▲		▲
	Determine the amount of particulate emissions from in-use diesel and gasoline-powered vehicles	▲				
	Characterize the emissions of light- and heavy-duty diesel engines with emphasis on the mutagenic components	▲		▲		
Health Effects	Study respiratory carcinogenicity of diesel fuel emissions (intra. instill)			▲		
	Evaluate tumor initiation of emissions from diesel rabbit and home heaters	△				
	Report on carcinoma formation using dermal exposure of sencar mice treated for tumor initiation (nine agents)	▲				
Health Effects	Recommend tier bioassay guidelines for use in evaluating unregulated emissions and fuels fuel additives		▲			
	Publish final report on bioassay of gaseous emissions from mobile sources		▲			
	Publish final report on evaluation of validity of model relating CO exposure levels to carbon-hemoglobin		▲			
	Publish final report on evaluation of cardiopulmonary effects of CO and O_3 in normals and patients with ischemic heart disease		▲			
	Publish final report of replication of EPA cardiovascular CO exposures in normals through measurement of systolic time intervals				▲	
	Publish final report on cardiovascular effects of ambient CO exposure at altitude				▲	
	Publish final report on effects of ambient CO on pregnancy outcomes					▲
	Publish final report on comparative carcinogenicity of mobile source pollutants using strain A mouse pulmonary adenoma model		▲			
	Publish final report on effects of carbon monoxide on neuro-behavioral development of the rat		▲			
	Complete all reports (7) of ongoing studies of inhalation of diesel emissions for various biological effects (lung tumor induction, lung cancer induction, pulmonary dysfunction mutations, sperm abnormalities	▲				

NONIONIZING RADIATION



Nonionizing radiation (NIR) is electromagnetic energy at frequencies below ultraviolet light. The NIR spectrum includes visible light, infrared rays, and radio frequencies (RF), ranging from below the low frequencies used for electric power transmission and distribution, to microwaves.

Every day the United States population is exposed to RF radiation from medical, industrial, and consumer product sources: radios, televisions, traffic radar, microwave ovens, electric power transmission lines, and satellite communications systems. As the number and power of existing NIR sources increases and as new applications of radiation are discovered, the public can expect its level of exposure to continue to rise.

Exposures to NIR, however, may or may not have human health effects. Effects have been documented for high power level NIR exposures, but the potential health effects at the lower levels common in most American urban areas remain unproven.

SIMPLIFIED SUMMARY OF HEALTH EFFECTS DATA BASED UPON EXPERIMENTAL ANIMAL RESEARCH*

Established Effects

- Cataracts $> 75\ \text{mW}/\text{cm}^2$
- Sterility $> 50\ \text{mW}/\text{cm}^2$
- Mutagenic effects $> 50\ \text{mW}/\text{cm}^2$
- Teratologic effects $> 25\ \text{mW}/\text{cm}^2$
- Cardiovascular effects $> 10\ \text{mW}/\text{cm}^2$
- Immunologic effects $> 5\ \text{mW}/\text{cm}^2$
- Behavioral effects $> 5\ \text{mW}/\text{cm}^2$

Unlikely Effects

- Cancer
- Life shortening
- Growth / Development

Suspected Effects

- Synergism with ambient temperature
- Synergism with drugs

Unknowns

- Health effects of chronic, low-level exposures
- Health effects of continuous exposure to ambient levels
- Mechanisms of action at low levels
- Dose response relationships
- Ecological effects

*Because NIR energy coupled into an absorber depends on frequency and absorber size and should be weighted for mode and time of exposure and animal species, this summary table is representative only.

This continuing scientific confusion about actual health risks from NIR exposure is partly responsible for the difference in occupational NIR exposure standards in various countries. The current U.S. *occupational* standard of $10{,}000\ \mu\text{W}/\text{cm}^2$ is about to be reduced by a factor of 10 to $1{,}000\ \mu\text{W}/\text{cm}^2$, yet the standards in effect in other nations are considerably more stringent: Poland $200\ \mu\text{W}/\text{cm}^2$, Italy $100\ \mu\text{W}/\text{cm}^2$, China $50\ \mu\text{W}/\text{cm}^2$ and the Soviet Union $10\ \mu\text{W}/\text{cm}^2$. Research gathered in the last decade to assess NIR health consequences is largely responsible for the proposed reduction of the U.S. standard but sufficient scientifically rigorous data are not available to support the lower foreign standards.

The problem of setting a *public* exposure standard is even more complex because the general population is usually exposed to far lower power densities than are those people who work near NIR sources. The median RF power density to which the American population is currently exposed is $5 \times 10^{-3}\ \mu\text{W}/\text{cm}^2$, about one billion times *greater* than RF radiation from natural sources but approximately one hundred thousand times *less* than power densities currently known to produce adverse health effects. However, exposures to power densities up to 10,000 times the median are known to occur, for example, high rise buildings topped by radio transmission towers or other buildings directly within line of sight of towers are exposed to such relatively high RF power densities. Because the health effects from these median and higher exposure levels are not clearly known, ORD's research on nonionizing radiation focuses on ultimately determining the health effects from the general population exposure levels.

This NIR health effects research program had its beginnings in the 1968 Radiation Control for Health and Safety Act. That Act directed the former HEW Bureau of Radiological Health to study NIR health effects and to set performance standards limiting NIR emissions from consumer products. Two years later EPA was formed and received the mandate to "advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards." The NIR health effects research program is now the largest intramural program of its kind in the United States. With ORD providing approximately 20 percent of the total federal investment in the research, the program assists EPA's Office of Radiation Programs (ORP) in developing RF radiation guidance. In addition, the program responds to ORP's technical findings; for example, when ORP monitoring showed that most public NIR exposure came from FM radio and UHF-TV frequencies, ORD set about finding the health effects of representative frequencies.

The NIR health effects research program has had significant results, particularly in the last four years. Its work on the health effects of radiation at broadcast frequencies has achieved international recognition. Increased cooperation between ORD, ORP, and the EPA Regional Offices has produced studies of near-field radiation patterns and gain measurements of FM radio and TV broadcast antennas, and has enabled each Regional Office to obtain NIR monitoring instruments (as recommended by ORP) to respond to public concerns about NIR. The NIR health effects research group has also designed and constructed a number of unique experimental exposure facilities.

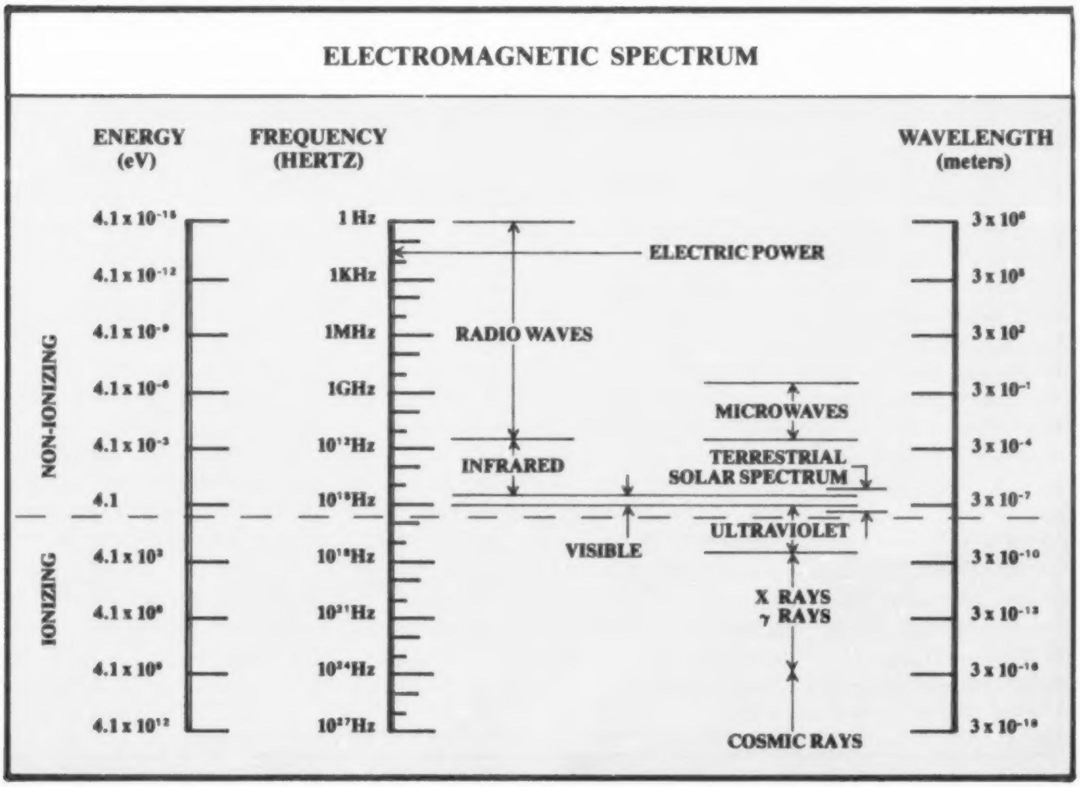
CURRENT NIR RESEARCH

ORD's research is currently developing information to:

- increase knowledge of the health effects of chronic, low-level exposures;
- build a data base about the human consequences of NIR exposures;
- promote understanding of the health effects of broadcast frequencies; and
- establish a population exposure standard for NIR.

Health effects of chronic low-level exposures. Adopting a University of Washington design, ORD constructed an economical system for conducting experiments in which animals are exposed to microwaves for 24 hours a day. The units are now being used in intramural studies. Proposals have been solicited for the design of systems that will continuously expose animals to NIR throughout their lifetimes.

The human consequences of NIR exposure. Data are now being gathered on two retrospective studies. The first will examine possible correlations between the incidence of five types of cancer and the patterns of RF density in a given urban area. An attempt will be made to correlate residences and places of work of people who have had breast, uterine, lung, and pancreatic cancers, and leukemia, with broadcast radio frequencies in the band 54-980 MHZ. The second study will determine the relations between high levels of radar exposure and the mortality and morbidity experiences of a select group of 1500 people whose occupations exposed them to radar over thirty years ago. Other studies will attempt to identify and characterize more population groups that could be investigated to determine NIR effects.



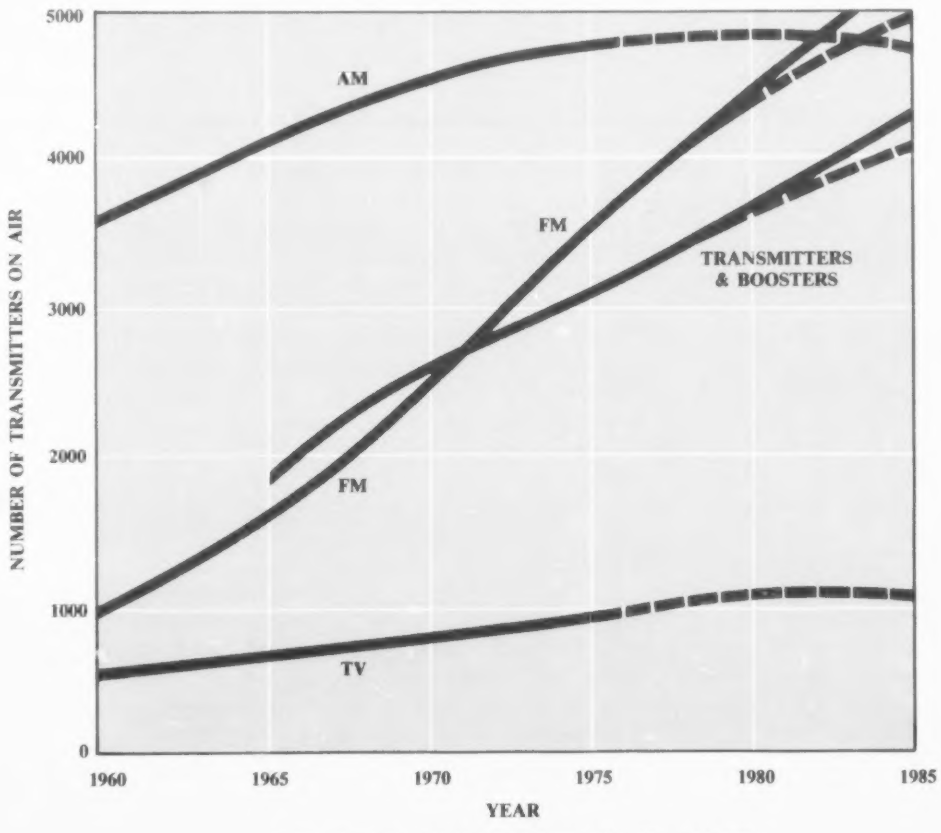
ELECTROMAGNETIC SPECTRUM

ENERGY (eV)
FREQUENCY (HERTZ)
WAVELENGTH (meters)
NON-IONIZING
IONIZING
4.1×10^{-15}
4.1×10^{-12}
4.1×10^{-9}
4.1×10^{-6}
4.1×10^{-3}
4.1
4.1×10^{3}
4.1×10^{6}
4.1×10^{9}
4.1×10^{12}
1 Hz
1KHz
1MHz
1GHz
10^{12}Hz
10^{15}Hz
10^{18}Hz
10^{21}Hz
10^{24}Hz
10^{27}Hz
ELECTRIC POWER
RADIO WAVES
MICROWAVES
INFRARED
TERRESTRIAL SOLAR SPECTRUM
VISIBLE
ULTRAVIOLET
X RAYS
γ RAYS
COSMIC RAYS
3×10^{8}
3×10^{5}
3×10^{2}
3×10^{-1}
3×10^{-4}
3×10^{-7}
3×10^{-10}
3×10^{-13}
3×10^{-16}
3×10^{-19}

Health effects of broadcast frequencies. ORD has recently completed studies on seven potential effects—teratologic, reproductive, physiologic, genetic, immunologic, hematologic, and behavioral—of extended exposures to broadcast frequencies. The effects were determined from responses of pregnant rats and their offspring to extended exposures of representative FM radio and UHF-TV frequencies. Results of the study revealed that at a level of 10 $\mu W/cm^2$ no effects were observed on any endpoint with the exception of elements of the immune system. Potential effects of a land-mobile frequency (e.g., CB radio) are currently being studied. Plans call for research to investigate the effects of AM radio and electric power transmission line frequencies.

A population exposure standard. Establishing a public NIR standard will continue to be a high priority, not only because of the increasing RF power densities to which the American population is exposed but also because of the findings that have supported a new occupational standard. ORD is assisting ORP in preparing a report on Radiofrequency Radiation Guidance, designed to protect the public from excessive exposures to RF radiation. Scheduled for completion in 1981, this document will be the first official U.S. position on public NIR exposure. ORD will conduct a comprehensive and critical review of available health effects literature to determine whether the current status of health effects knowledge is useful in setting exposure guides.

PROJECTED INCREASES IN BROADCAST SERVICES



Source: Electronics Industries Association, Electronic Market Data Book, 1977.

CURRENT IONIZING RADIATION RESEARCH

ORD also supports research into high-frequency radiation that has sufficient energy to ionize matter. When living tissues are ionized, cell damage occurs resulting in a variety of diseases and anomalies including cancer, developmental abnormalities, birth defects and genetic mutations. Sources of ionizing radiation range from nuclear weapons tests or research and nuclear power plants to diagnostic and curative tools such as dental X-rays and gamma ray cancer therapy. To deal with limited aspects of the problems associated with ionizing radiation, ORD has conducted an Offsite Radiation Safety Program at the Nevada Test Site (NTS) and a Quality Assurance Program.

The offsite radiation safety program. The Offsite Radiation Safety Program is charged with responding to a possible accidental release of radioactivity from the Nevada Test Site, where nuclear weapons research is carried out. Twenty-five continuously operating air monitoring stations situated within 200 kilometers of the NTS can provide early data in the event of accidental release of radioactive effluents. Milk is sampled at 24 locations around the NTS. Additional air samplers and a stand-by milk surveillance network exist if needed. Within the last decade this continuous monitoring support has been reduced to its present level, thanks to heightened safety criteria and successful containment of underground tests. Radioactivity has not been released from the NTS since December, 1970.

However, increased emphasis has been placed on assessing the potential contamination of groundwater sources from underground testing. An extensive network of monitoring stations continuously take measurements to assess seepage of radioactive noble gases through the soil and to the surface. A similar research effort to identify the environmental impact of two nuclear tests conducted at the Tatum Dome Site in Mississippi involves groundwater surveillance. That program seeks to pinpoint sources of excessive tritium found near the surface ground zero of the explosions.

Assessment of the effects of other previous nuclear tests is also under way. Residents of offsite areas in Nevada and Utah are being studied to reassess radiation exposures and probable doses from aboveground testing in the 1950's and early 60's. ORD is conducting the research in conjunction with a number of other government agencies and laboratories.

Two major events affected the Offsite Program in 1979. First, the program was transformed from a large-scale continuous surveillance operation to an emergency response effort. At this time, the number of personnel assigned to the program was reduced from 90 to 52. The current staff is providing monitoring support and emergency response. All radiochemical analyses requiring a significant lead time are performed by contractors. However, there has been no reduction of the number of public safety and monitoring personnel deployed to offsite areas during and immediately following each test. Instrumented aircraft are also airborne for each nuclear detonation.

The second event was the accident at the Three Mile Island (TMI) nuclear power plant. A large trained staff of radiation specialists from the Offsite Program was dispatched to TMI to determine the risks to public health and safety and the environmental impacts from radiation releases from the plant. The responsibility for monitoring and surveillance activities of this type will be continued in FY 1982 by EPA's Office of Radiation Programs.

The quality assurance program. In 1972, a National Radiation Quality Assurance Program was established at ORD's Las Vegas laboratory. The main purpose for that program was then, and remains today, to distribute reference samples of known radioactivity to laboratories that measure environmental radiation; currently the program supports over 40 studies and annually delivers more than 4600 samples to 200 laboratories.

Besides this sample supply function, other responsibilities have been levied on the program. Since 1974, program personnel have conducted studies with the National Bureau of Standards to assure accuracy of the samples and subsequent traceability of measurements made by the Las Vegas laboratory to the National Radiation Measurement System. In 1977, the program was given responsibility for the on-site evaluation of laboratories that analyze drinking water. Since inception of this effort, 49 laboratories have been evaluated.

Another responsibility given the Quality Assurance Program is the review and evaluation of alternative (as opposed to EPA-approved) radiochemical testing methods that some laboratories want to use. Applicants who want to use the alternative methods are being asked to determine the precision and accuracy for both the EPA-approved methods and their proposed methods. Such determinations will provide an equivalent basis by which to compare the methods; however, before the alternative methods can be approved by EPA, approval criteria and procedures that comply with National Interim Primary Drinking Water Regulations (NIPDWR) need to be established, documented, and made available to the applicants. A report that satisfies these approval requirements will be produced.

EMERGING NIR PROBLEMS AND POSSIBLE RESEARCH NEEDS

The NIR research program has identified two problem areas that are likely to merit study over the next five years:

- direct broadcast satellites (DBS); and
- electric power transmission lines.

Direct broadcast satellites have been providing home television reception in Canada since 1976; more DBS spacecraft may be launched in early 1984 to serve Japan and Western Europe. Service to the United States is clearly a possibility in the near future and is therefore a potential new source of public NIR exposure. DBS for the United States would operate at frequencies of approximately 12 GHz which would pose minimal potential health impacts according to theoretical frequency-to-absorber size relationships. However, no health effects studies have been conducted in this frequency range to verify the theory.

Another emerging problem is potential NIR effects from electric power transmission lines. Electric power lines in the United States are commonly operated at 500 kV, although some lines use 765 kV. Power companies and the Department of Energy are actively pursuing research and demonstrations for 1200 kV lines, with an eye toward commercial deployment in the 1980's. The electric and magnetic fields from these new lines would be of very high intensity; furthermore, because of increasing difficulties in acquiring power transmission line corridors, these new lines will probably be strung along existing routes and easements. The health effects of such high intensity electric and magnetic fields on people along the routes are unknown.

FUTURE PROBLEMS

Two energy-related developments are expected to raise questions for NIR researchers by the late 1980s:

- a satellite power system (SPS); and
- magnetically levitated vehicles.

DOE is evaluating the satellite power system as an energy supply alternative. With a surface area of 50 kM^2 a satellite in geosynchronous orbit would collect solar energy that could be converted to microwave energy and beamed to a 140 kM^2 land-based rectifying antenna. The energy could then be converted to electricity and distributed by standard power lines. A complete SPS system would consist of 60 satellites and would raise general population NIR exposures to 100 to 1000 times the current level. The satellites would probably transmit at 2450 MHz. While there is much data on the effects of this frequency since it is currently being studied to determine biological effects of NIR, critical information on long-term exposure effects is lacking. The effects on birds which might fly through the beam, on potential agricultural yields and on other aspects of the ecology are practically unknown. However, if the satellites were to transmit at 4950 MHz or with a laser transmission system, even less would be known about the health and ecological impacts.

An even more exotic problem involves a new form of transportation. Strong magnetic fields from high direct current electricity sources placed under a vehicle have been sufficient to raise the vehicle into the air. Before such magnetically-levitated vehicles became a common form of personal transport the magnetic field effects within the passenger compartment would need investigation.

NONIONIZING RADIATION RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Effects of NIR	Conduct multi-disciplinary study to determine effects on rodents exposed from conception to adulthood to an FM radio frequency	▲				
	Study primate infant mortality during pre- and post-natal exposure to microwave oven frequency	▲				
	Conduct multi-disciplinary study to determine effects on rodents of 22 hours/day exposure to a land mobile frequency	—	▲			
	Conduct experimental studies of 60 Hz (electric power line frequency)		—	—	▲	
	Conduct experimental studies of lifetime exposure of rodents to a resonant frequency			—	■	
	Correlate cancer incidence and RF emission density in a U.S. city	▲				
	Track mortality and morbidity of workers exposed to radar during World War II	—	▲			
	Identify and characterize potential populations for epidemiological studies of NIR effects	▲				
	Conduct epidemiological studies of selected populations		—	—	—	■
Mechanisms of Action	Examine effects of bipolymers	▲				
	Examine effects on natural and synthetic membranes	—	—	—	▲	
	Examine mechanisms and implications of calcium release from brain tissues by AM radiation	—	—	▲		
	Determine local and generalized thermal physiological responses of rodents and primates to NIR	—	—	▲		
	Study effects of NIR on energy metabolism in intact rodent brain	▲				
	Examine interaction of NIR with nerve membrane functions	▲				
Dosimetry and Experimental Exposure Facilities	Measure whole body average NIR energy input using manual twin-well calorimetry	▲				
	Develop computer-assisted twin-well calorimetry system	▲				
	Analyze internal NIR energy deposition using infrared thermographics	▲				
	Construct 970 MHz animal exposure facility	▲				
	Construct rodent lifetime facility	—	—	▲		

▲*Final report, manual or user's guide;* △*Interim report or manual;* ●*Prototype equipment and report;*
★*Interim or final criteria formulations;* ○*Final protocol;* ■*Continuing effort;* ☐*Other, self-explanatory*

PESTICIDES

49'er
GOLD STRIKE
MALATHION-50
Premium Grade
CONTROLS INSECTS ON PLANTS AND AROUND BUILDINGS
CAUTION
Keep Out of Reach of Children
See back panel for other cautions
NON -25
GARDEN
NTROL
B-1

Pesticides play a vital role in our economy and in our lives. They help create our country's abundance of food and fiber and protect the public health by controlling insects and other pests. But because pesticides are primarily designed to kill or otherwise affect the behavior of living organisms, they must be considered potentially hazardous. Pesticides pose hazards not only to humans but to other life, including wildlife and livestock, as well. They must, therefore, be carefully controlled in the environment.

Some of the pesticides that were developed during or immediately following World War II were put into immediate and wide use in agricultural production; these pesticides were chemicals that persisted in the environment long after application. Today, several billion pounds of pesticides are used annually in the

United States, but many of the newer pesticides are less persistent than the older forms. The near future will see the continued development of degradable pesticides and pest control methods that rely more on biological control than on chemical control.

Because of increasing awareness about the accumulation and effects of persistent pesticides, which have been found in air, water, soil, and human tissue samples, there is a great deal of public concern about the safety of these compounds. Since 1970, EPA has banned most uses of some persistent chemicals, e.g., DDT, mirex, kepone, aldrin, dieldrin, chlordane, and heptachlor, and is now encouraging the use of integrated pest management strategies as a means of reducing the use of pesticides while maintaining adequate pest control.

Protecting the Public and the Environment

Two laws that protect the public and the environment from the potential hazards of pesticide use are the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended, and the pesticide amendments to the Federal Food, Drug, and Cosmetic Act (FFDCA). The FIFRA requires a premarket clearance by EPA of all pesticide products to be used in the United States. The FFDCA permits EPA to establish a tolerance (acceptable residue level) for pesticide residues in food or livestock feed crops.

The FIFRA, which was amended in 1972, 1975, and 1978, requires EPA to balance the risks and benefits of a pesticide's use. Manufacturers are required to send to EPA data about the risks of a pesticide's use; these data typically encompass mammalian toxicology (primarily studies on laboratory animals), chemistry, environmental fate, and fish and wildlife hazard studies. EPA has the authority to deny registration or, in cases of products already on the market, to cancel or suspend registration if the risks from certain or all uses of a pesticide are found to outweigh the benefits to society.

The amendments to FIFRA gave EPA two major tasks to accomplish: the reregistration of all pesticides now on the market and the classification of all pesticides into either "general" or "restricted" use. Restricted use means that a pesticide is to be used only by or under the supervision of trained, certified applicators. More than a million farmers and professional applicators have been certified to handle restricted-use pesticides, and more than 2000 pesticide products have been or are proposed to be restricted.

EPA has embarked on the massive job of reregistering some 35,000 pesticide products (made from about 1,500 principal active ingredients) in accordance with the most current scientific standards. An EPA proposal, which Congress incorporated in the 1978 FIFRA amendments, is that reregistration and future registrations be accomplished through development of registration standards. The standards will enumerate all approved formulations, uses, and restrictions, and will be based on all relevant data about a pesticide's effects, including the same kinds of data now required for regulating new products but never before collected for the older pesticides. This approach to pesticide registration offers the advantage of making only one comprehensive risk/benefit decision per chemical, rather than the resource-intensive and inefficient product-by-product approach taken in the past. Even with the new approach, the enormous task of developing registration standards for all pesticides will take approximately 10 to 15 years.

In addition to registering and reregistering pesticides, EPA enforces compliance with FIFRA requirements by the pesticide-producing industry and by users and applicators of pesticides. The EPA enforcement program, conducted in cooperation with state agencies as mandated by the 1978 FIFRA amendments (states have primary use enforcement), includes registration of pesticide-producing establishments, product sampling and label checks at production sites and in the marketplace, certification and observation of pesticide applicators, laboratory audits, and inspections to ensure that good laboratory practices are being observed. As part of the enforcement activities, pesticide products are analyzed and their uses investigated at the request of the states; technical staff are trained in investigation techniques and product analysis; and a quality assurance check sample program is provided for participating state pesticide chemistry laboratories.

CURRENT RESEARCH

EPA's current pesticides research program is designed primarily to establish and maintain a sound scientific basis for pesticide regulation and compliance enforcement activities. The program focuses mainly on developing knowledge, data, and techniques to assess potential health and environmental risks from pesticides; quality assurance and technical assistance help assure appropriate applications of the research results.

Research to improve the quality of pesticide risk assessments will reduce the uncertainty under which regulatory decisions are now made and will increase the knowledge and understanding about the extremely complicated environmental and physiological phenomena involved. Such risk assessment depends on reliable measurements or predictions of a pesticide's behavior and effects as results of its proposed uses before such uses are allowed. Risk assessment data and information come from specific field or laboratory tests of the pesticide chemical, knowledge of its interactions with the environment, and identification of the exposed populations that should be protected. Guidelines for conducting risk assessments are under continuing review and, when appropriate, are revised to include new techniques.

To evaluate the potential human health and environmental hazards from a pesticide, EPA attempts to identify and characterize the populations at risk, assess the severity of the populations' exposures, and determine the actual or potential adverse effects on health and ecosystems. Of these three factors, determination of adverse effects of pesticides is most advanced; therefore, EPA's current research emphasizes exposure assessment, for which data are sparse and for which measurement and predictive techniques are relatively undeveloped.

Human Risk Assessment Research

The development and validation of procedures to estimate human exposures to pesticides under a variety of conditions is an area of major concern. For example, one such procedure urgently needed would define the conditions under which agricultural workers could safely re-enter pesticide-treated fields. These and other procedures will be integrated into registration guidelines as a part of the data requirements for pesticides.

Exposure measurements can be made either directly or indirectly. Direct methods trap a pesticide as it comes into contact with a person, the trapped amount representing the exposure. Indirect methods measure exposure in terms of a pesticide's effect on an exposed organism. Among the parameters used to measure pesticide exposure indirectly are storage of residues in tissues, excretion, and enzyme inhibition.

A number of direct methods for estimating human exposure to pesticides have already been developed and validated by EPA, and it is expected that future research will concentrate on refining indirect methods.

Because people employed as pesticide applicators, formulators, spray pilots, and in other similar positions receive a relatively high intensity and frequency of exposure, they command a priority in the program's human risk assessment effort. Also of significant concern, however, are the widespread exposures of urban residents to pesticides during home and garden use. Those pesticides in common use by the general public are being studied to establish usage patterns and their attendant risks.

Much of the research into the human health effects of pesticides involves the use of carefully selected experimental animals. From these studies, acute, chronic, and subchronic toxicities can be determined. Among the tests run are those for reproductive and neurophysiological effects, and those that evaluate teratogenic, mutagenic, and carcinogenic effects. Pharmacodynamic studies provide information on rates of absorption from dermal and inhalation exposures, and metabolic studies define biotransformations. Results of this research are used to verify data submitted by pesticide registrants or to fill the gaps in the data sets used for human risk assessments. The success of this effort depends partially on being able to measure extremely small concentrations of pesticides and their metabolites in tissue and exposure media. To this end, sophisticated techniques are being developed with emphasis on high performance liquid chromatograph/mass spectrometer methods and improved air sampling techniques.

To reduce the complexity and costs of the human risk assessments, research will explore the possibility of extrapolating human exposure from one pesticide compound or use to other, similar compounds or uses. Research will explore the use of surrogate compounds in lieu of separate studies for each individual pesticide. If these efforts prove successful, much expensive and time-consuming exposure testing by EPA and by pesticide manufacturers can be eliminated.

Environmental Risk Assessment Research

Pesticides that enter the environment are transported through soil, water, or air, where they may undergo chemical and biological transformation, affect both target and non-target organisms, and sometimes enter the human food chain. The task of risk assessment involves estimating expected concentrations of pesticides in the environment and in organisms, gauging pesticide effects and judging the significance of this presence and effect on environmental quality and human health. Currently the tools used in environmental risk assessment are limited to the most significant factors: the acute and chronic toxic effects in representative aquatic and terrestrial species, and the individual chemical, physical, and biological processes that transform and transport pesticides and that result in organism, community, and ecosystem exposures. Future EPA pesticides research will continue to refine these tools as it develops predictive exposure estimation techniques and improved laboratory tests to produce the chemical and environmental data necessary for exposure predictions.

In conjunction with other EPA water quality and toxic substances research efforts, numerical models of environmental transport and transformation of pesticides are being tested in controlled laboratory aquatic and terrestrial ecosystems and in semicontrolled field studies in outdoor natural systems. The models are refined until they are satisfactory for use in environmental risk assessments. Models of the transport and accumulation of pesticides in food chains are also being developed, as is the technology that allows these complicated models to be conveniently and expeditiously employed in risk assessments. Providing a basis for the latter effort are EPA research and development products, such as the Exposure Analysis Modeling System (EXAMS).

Data to determine the effects of environmental exposures are being generated by tests that measure the acute and chronic effects of pesticides on a variety of aquatic and terrestrial organisms. Among these techniques perhaps the most important are those capable of measuring sublethal chronic effects, as results from this testing allow researchers to estimate a pesticide's "worst case" effects. Chronic tests are also available for testing a pesticide's effect on reproduction in several fish species, in insects, crustaceans, mollusks, annelides, and in both rooted and planktonic plant species. Research will continue to improve the utility and specificity of these tests and the interpretation of their results for risk assessments.

Effects of pesticides on communities of organisms and on ecosystems are studied using laboratory simulated ecosystems, or microcosms. A precise understanding of how these ecosystems function does not exist, which makes the interpretation of test results difficult. As a consequence, work is focusing both on the development of ecosystem research methodology and on the identification of phenomena that govern the transport, accumulation, uptake, metabolism, and elimination in the biotic and abiotic portions of aquatic and terrestrial ecosystems.

As various environmental effects test methods are developed, they are applied to new or representative pesticides either to confirm data furnished EPA by registrants, or to fill in data gaps.

Quality Assurance for Measurement of Pesticide Residues

Because accurate measurement of pesticide residues is critical for determining exposures, monitoring environmental and human pesticide burdens, and assessing pesticide effects, ORD provides a quality assurance program. To supply analysts with suitable reference and calibration materials, ORD maintains a repository of pesticide chemicals of known purity. Reference samples of pesticide chemicals in a variety of environmental materials are available to laboratories to help them maintain satisfactory performance of their measurement systems. Analytical supplies, rigorously examined for compliance with quality control specifications, are also furnished to EPA's national monitoring network for developing data on human and environmental pesticide residues.

Integrated Pest Management

A secondary focus of EPA's pesticides research is on integrated pest management (IPM) strategies that minimize the introduction of pesticides into the urban environment, reduce general pesticide exposures in urban settings, and moderate the current dependence on chemicals to control urban pests.

IPM is a comprehensive systems approach for keeping pest populations at acceptable levels by taking maximum advantage of natural pest controls, such as predators or weather, and by balancing the use of chemical, biological, and cultural pest controls. Since each pest-host system requires a tailor-fitted IPM strategy, development of IPM systems must be supported by several points: (1) a basic understanding of pest population dynamics; (2) a recognition of appropriate pest control agents; (3) highly selective methods for using chemical pesticides; (4) alternative non-chemical pest control methods; (5) models for integrating alternative pest control methods; (6) social and economic analyses of each new IPM strategy; (7) demonstration of optimal strategies; and (8) education of government officials and pest management specialists for the IPM strategies' acceptance and use. EPA's IPM research, which is mandated by FIFRA, has concentrated on developing IPM strategies for mosquitoes in ricelands and on protecting apples, alfalfa, cotton, corn, and soybeans.

In 1982, agricultural IPM research initiated jointly by EPA and USDA will be continued wholly by the Department of Agriculture. EPA will, however, continue an IPM research program on controlling urban pests. Concentration will be on the development of strategies for household pests, garden and turf, ornamental, and shade tree pests.

EMERGING RESEARCH NEEDS

Future pesticides research needs will either emerge as a result of gaps in existing knowledge being identified, or as the nature of the pesticides themselves and the manner in which they are applied and used alters. Examples of the former are the presently emerging needs for research into the effects of the inert ingredients in pesticides, and the need for a deeper understanding of how ecosystems function when exposed to pesticides. Examples of the latter include studies of biorational pesticides and of improved application methods. Not falling into either category, but potentially important, is research to select representative species in the natural environment capable of providing researchers with an "early warning system" that signals a pesticide's potential for endangering human health.

Biorational pesticides. Most of EPA's pesticide risk assessment techniques were developed to evaluate the risks from conventional chemicals; however, an increasing number of pest control agents now being developed have as their active ingredients microorganisms and certain naturally occurring biochemicals, such as plant growth regulators, insect pheromones, and insect hormones. These "biorational pesticides" control pests in manners distinctly different from most chemical pesticides, and thus will require new methods to test for risks.

The number of candidate biorational pesticides is currently very small but is expected to grow steadily over the next five years. EPA is now developing guidelines for the testing of biorational pesticides prior to registration.

Some current research is developing data and test techniques for identifying potential human health effects of baculoviruses; future risk assessment for biorationals will likely emphasize identification of the abilities of certain agents to infect and/or produce adverse effects on non-target organisms. Our research will concentrate on techniques for judging potential health and ecological effects; then, as a clear picture of such effects emerges, the research will attempt to examine the ability of biorational agents to survive and replicate in the environment. The first priority for this research will be to develop basic laboratory tests that determine the pathogenicity or toxicity of microbial pest control agents in representative non-target organisms (such as mammals, birds, fish, aquatic invertebrates, and algae). Of lower priority will be the development of adequate methodologies for the detection of biorational pesticides.

Effects of inert ingredients. Limited resources and time have restricted EPA's risk assessments and supporting research to the active ingredients in pesticide formulations, leaving the potential problems posed by so-called inert ingredients yet to be addressed. As a consequence, the significance of exposures to these ingredients—solvents, emulsifiers, spreaders, stickers, thinners, and related agents—is poorly understood, and little is known about the combined effects of the inert and active ingredients. Too little is also known about the impurities found in pesticide formulations which may result in increases in formulation toxicity either because the impurities themselves are toxic or because of their potential to enhance the toxicity in active ingredients.

Improved studies of ecological effects. Research using small aquatic microcosms as experimental tools has shown that simple tests of pesticide effects on ecosystems will be much more difficult to develop than had been originally envisioned. Our recognition of the complexity and diversity of ecosystems has, for example, diminished the potential use of microcosms as toxicology screening tools; on the other hand, that very complexity and diversity has substantially increased the importance of microcosms for learning more about how ecosystems operate and how pesticides affect them. Progress in extending the investigation of pesticide effects on single species to populations or whole communities has been slow but will have to increase over the next five years if FIFRA risk assessments are to consider ecosystem effects.

Early warning. The detection of pesticide accumulation or pesticide degradation products in wildlife provides an "early warning" of potential human exposures. Plants and animals could be monitored for disorders that might be analogous to human disorders, thereby alerting researchers that a pesticide threat is possible. Needed for this warning, however, will be improved techniques for discerning subtle ecological effects that result from approved uses of pesticides. The early warning, in effect, would be a retrospective empirical risk assessment that would supplement the prospective assessments from ecological effects tests.

The warning information would be able to help us better understand the migration and ultimate fate of the pesticides and their degradation products and thus improve environmental risk assessment techniques.

Quality assurance for measurement of biological effects. Risk assessments will increasingly depend on measurements of biological effects. These measurements require a system of quality assurances for the in vitro biological tests in order to ensure that the accuracy and precision of the measurements are comparable to chemical measurements which are currently subject to rigorous quality assurance procedures.

Improved application technology. Improved technology for applying pesticides will reduce exposures of non-target organisms and will complement both EPA's urban IPM program as well as the USDA agricultural IPM program by reducing the quantity of chemicals needed to adequately control pests. Our goal will be to develop technology that puts pesticides where they are needed in the necessary amounts, thereby optimizing target organism exposures and minimizing non-target organism exposures. Promising pesticide application technology already under development will be identified and evaluated and its demonstration accelerated.

FUTURE TRENDS

Two future trends are likely for pesticides in America: Today's pattern of pesticide use will change, and there will be a call for better testing of pesticide hazards.

Patterns of use. Total domestic chemical pesticide use is projected to increase by about 5% during the next decade. The use of herbicides is expected to increase by nearly 20%, but the domestic and agricultural use of insecticides is expected to decline. This decrease in the use of chemical insecticides may reflect a trend towards more integrated pest management and the introduction of biorational insecticides. The decrease could be greater, however, if integrated pest management research programs are successful and industrial development of biorational pesticides is accelerated. The anticipated increase in herbicide use also may reflect the wider application of minimum-tillage farming to conserve energy. Increases in the use of other agricultural chemicals, in particular, plant growth regulators that promote productivity and crop quality, are also likely to take place in the future.

Testing of hazards. Public concern about the potential hazards of pesticides will result in the continued demand for more thoroughly tested, environmentally compatible pesticides; this demand will continue the current emphasis on safety testing. A great need to test pesticides as well as other new chemicals could overwhelm the nation's capability for testing and assessing the risks of these chemicals' use. EPA intends to devote research efforts to developing the more efficient testing systems that will be needed. As IPM strategies increasingly dictate the use patterns of pesticides, EPA will also develop the improved testing protocols that will be needed to discern the broader implications and subtle risks of these patterns.

PESTICIDES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Quality Assurance	Provide to OPP epidemiology monitoring laboratories standardized analytical support materials such as GC column packing and florosil absorbents	—	—	—	—	■
	Maintain electronics calibration and repair service	—	—	—	—	■
	Maintain a repository of pesticidal chemicals of known purity for distribution to laboratories	—	—	—	—	■
Health Effects	Determine the infectivity of baculovirus to cells of mammalian and other nontarget species	▲				
	Report on human exposure during home and garden use of pesticides (endosulfan, diazinon, and carbaryl)	▲				
	Report on air sampling devices for pesticides	▲				
	Report on role of material toxicity on supernumerary rib formation	▲				
Ecological Effects	Examine the interaction between agricultural chemicals (fungicides, herbicides, and/or fertilizers) and soil microflora and determine the results effects on the degradation of insecticides as affected by the environmental conditions	△	▲			
	Report on static tests of the acute effects of pesticides on marine animals	▲				
	Determine pathobiological effects of chemical pesticides and biological control agents	▲				
Methods Development: Freshwater	Compare the acute and chronic toxicity and persistence in fish and aquatic organisms of five or six encapsulated (slow release) and technical grade pesticides	▲				
	Determine the acute and chronic toxicity of OPP-designed pesticide compounds on fish and freshwater invertebrates in flowing water test systems	▲				
Methods Development: Marine	Report on the development of acute life cycle toxicity test methods with saltwater invertebrate species	▲				
	Report on the effects of pesticides on growth of marine unicellular algae	▲				
	Organize and manage PEEAT; initiate establishment and execution of its operational and coordination procedures	—	—	—	—	■
	Determine the transport (including metabolism, fate, and potential for exposure) of 2,4,D in a terrestrial microcosm	—	▲			

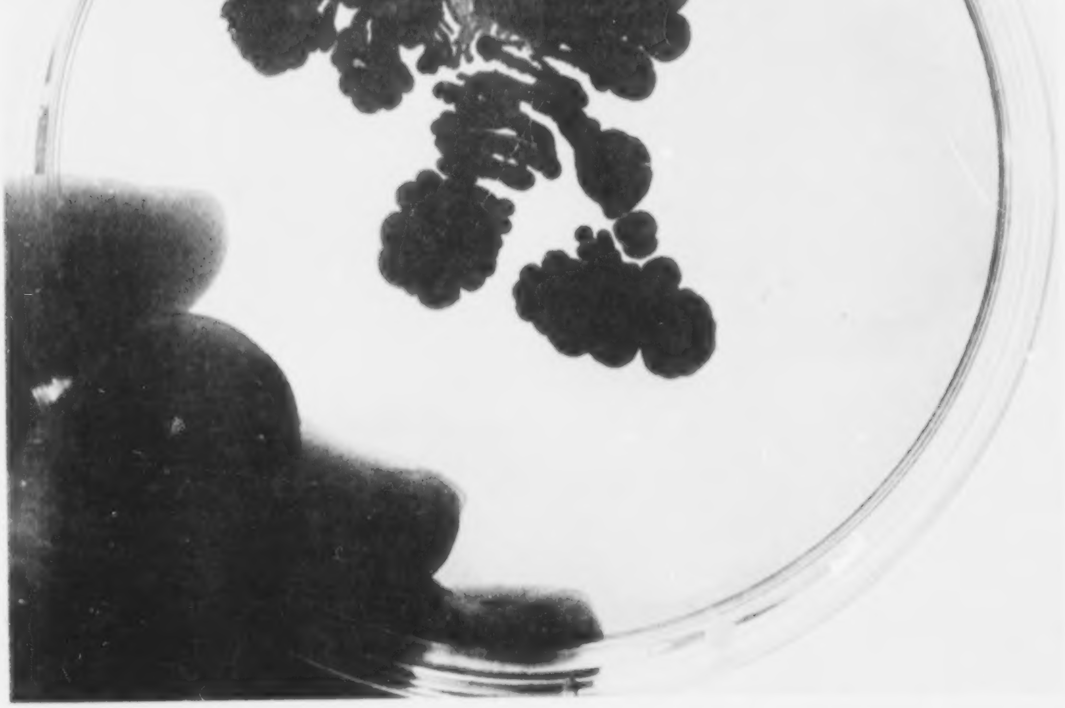
▲Final report, manual or user's guide; △Interim report or manual; ●Prototype equipment and report;
★Interim or final criteria formulations; ○Final protocol; ■Continuing effort; □Other, self-explanatory

PESTICIDES RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Methods Development	Develop rationale and methodology for improving the protocols for sorption and chemical and microbial transformation of pesticides in soils and aquatic environments for possible incorporation into the Pesticides Registration Guideline:					
	(a) Collect information on soil/sediment sorption mechanisms	—	—	—	—	— ■
	(b) Collect information on pathways of microbial transformation in the aquatic system	—	—	—	—	— ■
	(c) Collect information on pathways of chemical transformation in aquatic systems	—	—	—	—	— ■
Integrated Pest Management (IPM)	Develop IPM strategies for:					
	(a) cotton, alfalfa, apples, and soybeans	— ✱				
	(b) corn-soil insects	— ✱				
	(c) riceland mosquitoes	— ✱				
	(d) urban shade tree pests	—	— ▲			
	Develop tactics for controlling musk thistles in U.S. pasture and rangeland	— ▲				
	Develop integrated management strategies for aquatic weeds	—	—	—	— ▲	
Scientific Assessments	Provide oversight or evaluations on carcinogen risk assessments	—	—	—	— ■	
	Provide mutagenic risk evaluations	—	—	—	— ■	
	Provide limited oversight of exposure assessments for consistency	—	—	—	— ■	
	Provide support to Office of Enforcement hearing	—	—	—	— ■	
	Provide oversight of mutagenic risk evaluations			—	— ■	

✱ *To be continued by USDA in FY 1982*

TOXIC CHEMICAL TESTING AND ASSESSMENT



Industry in the U.S. has followed a course of steady growth, resulting in a wide variety of economic, medical, agricultural, and other benefits for the general public. Along with this growth, however, has come an increase in the manufacture, use, and disposal of chemicals, with over 70,000 separate compounds being manufactured in the U.S. today, at least 50 of which are produced at quantities exceeding 1.3 billion pounds annually. Projections indicate that this present rate of production will triple or even quadruple by the year 2000. These projected increases will undoubtedly have a significant impact on the presence of toxic substances in the environment, as well as on the attendant potential increases in adverse health and environmental effects.

Extensive environmental legislation has been promulgated over the past decade to address the wide array of problems accompanying toxic chemical usage. Initially this legislation focused on specific media (e.g., the Clean Air Act and the Safe Drinking

Water Act), and sought to mitigate rather than prevent the harmful effects of toxic substances. The specificity of this legislation, however, and its somewhat limited scope often resulted in gaps in the information and authority required by EPA to address the pervasive toxic substances problem. It was to fill these gaps that Congress in 1976 passed the Toxic Substances Control Act (TSCA).

The broad authority provided by TSCA, in conjunction with the information and authority already afforded by previous environmental legislation, has given EPA a firm foundation upon which to support its toxic substances research program. Consequently, a major priority of this program is the effective implementation of TSCA's key provisions.

Control action under TSCA can only be exercised when action cannot be authorized under other legislation. When invoked, however, TSCA can provide broad information gathering, chemical screening, testing, and chemical control authorities, serving to protect public health and the environment both by restricting the entrance of hazardous new chemicals into the environment and by limiting exposure to those already present.

Key provisions of TSCA allow EPA to:

- require manufacturers or processors to test already marketed chemicals for potential health and environmental effects under certain specified conditions;
- require notification prior to the manufacture of new chemicals or chemicals proposed for significant new uses (Premanufacture Notification);
- limit the processing, production, transport, disposal, or use of chemicals to prevent unreasonable health or environmental risks;
- require reports or health and safety studies from industry concerning commercial distribution and exposure to toxic substances.

Early implementation of TSCA has focused on the Act's evaluation aspects—data collection and risk assessment—and on the premanufacture notification provisions.

Implementation strategy and associated research needs. To date, the rate of chemical production has far exceeded advances in the discovery and mitigation of the problems toxic substances present. Developing such data upon which to base regulatory decisions in the implementation of TSCA is the primary concern of ORD's toxic substances program. In concert with overall toxics research needs, the Office of Research and Development participates in overall toxics integration activities through the Toxic Substances Priorities Committee (TSPC). The committee serves to identify toxics-related activities of concern throughout the Agency and has representation from each of the Assistant Administrators' offices.

Of particular importance to this effort is the development of suitable tests to evaluate adverse effects. At the present stage of TSCA implementation, ORD is working to evaluate the accuracy of new or established testing procedures to predict hazards to humans and their environment. Research is being conducted to find better methods with which to quantify human exposures to specific materials. Additionally, studies of the environment and various ecosystems are being conducted to evaluate chemicals of current concern.

In pursuit of this goal, FY 1978 and 1979 activities focused on developing an initial set of test standards for health and environmental effects testing. Activities for FY 1980 and 1981 stress revision and expansion of these test methods, as well as the development of tests for chemical characterization, fate, and environmental effects.

Developing and validating test methods and monitoring systems to evaluate the ecological effects and chemical fate of toxic substances in the environment is one of the program's most pressing needs. Once such predictive methods are established, potentially hazardous chemicals can be identified *before* their introduction into the environment. This is to be contrasted with the situation in the past when the delayed health and ecological effects of a chemical released into the environment have not been identified until as many as twenty to forty years have passed. Examples of diseases with long latency periods and known to be caused by toxic substances range from mesothelioma (a form of lung cancer) that can follow long after exposure to asbestos, to bladder cancer in those exposed to beta-napthylamine, a chemical used in the aniline dye industry.

Since its passage in 1976, much progress has been made toward TSCA implementation, though much of this progress must be considered primarily as a foundation for future, more comprehensive accomplishments and the eventual effective control of toxic substances in the environment. Accomplishments to date have established a general direction for the effective control of toxic substances in the environment, and have also identified substantial deficiencies in those methods available to assess risks to man in the environment. It is expected that support for implementation of TSCA will remain a major goal of ORD and the Office of Pesticides and Toxic Substances (OPTS) for at least the next fifteen years, and that this process will require ongoing and extensive testing and assessment research.

THE RESEARCH PROGRAM

A tiered testing approach has evolved in the ORD development of its toxic substances test methods. It is an approach which utilizes quick and inexpensive preliminary tests to determine the need for more thorough studies, and thus directs scarce human and financial resources to the chemicals and situations which pose the greatest risk. Assessment begins with an initial screening to determine whether a chemical requires further investigation. If this screening establishes that the compound may pose a significant risk, but there are insufficient data to determine the extent of the risk, the compound is then carried through a progressively more detailed testing and assessment process where the risk is analyzed and quantified.

Research and risk assessment conducted by ORD and OPTS in support of TSCA falls into four major areas:

- health effects;
- environmental fates and effects;
- monitoring and quality assurance; and
- chemical control.

Chemical testing and assessment requirements are currently the major focus of all four research efforts. However, as the data base grows, and as implementation matures causing discharges of certain chemicals to stop, a larger portion of program resources will flow into regulatory activities. Greater needs for research and support will be generated by regional programs and by the Office of Enforcement, which will oversee implementation of the regulations.

Health Effects Research

Tests used in health effects research must economically generate the best possible assessment of a chemical's role in producing or exacerbating human diseases. Also to be considered in the research are the availability of suitable alternatives to the chemical and the size of the population likely to be impacted by its use. Such considerations must be balanced against the potential harm to humans and the environment in order to arrive at a defensible regulatory stance.

A defensible and affordable toxic substances strategy depends upon health effects research which has included consideration of several fundamental questions:

- What is the full range of diseases that can result from exposure to toxic chemicals or chemical classes?
- How can we define the appropriate test systems or animal species to be employed for detecting chemically-induced adverse health effects? How can this be done cost-effectively and, most importantly, reliably?
- What basic and critical factors must be considered concerning the metabolism, pharmacokinetics, and repair processes in the body's interaction with a chemical? How is chemical damage caused and how can information derived from other species be extrapolated qualitatively and quantitatively for use in humans beings?
- What place do humans occupy in the range of sensitivities expressed by various species to particular types of toxicity (i.e., interspecies comparisons of intrinsic sensitivity)?

Answers to these questions are being pursued in all seven health effects research program areas—general toxicology, developmental toxicology and reproductive effects, neurotoxicology, mutagenicity, carcinogenicity, metabolism, and epidemiology. ORD's tiered testing approach is used in this quest wherever appropriate (i.e., screening, confirmation, and risk assessment levels).

Research in general toxicology involves the development and validation of test systems and animal models to serve as predictors of human disease processes and particular target organs potentially affected by toxic chemicals. First, we must determine the utility and predictive power of currently available data, drawn from experimental trials, human monitoring observations, and test systems now under development. Once evaluated, the more wide-ranging of these tests will eventually be incorporated into the tiered testing scheme for use as initial screening tests. The more specific tests will help form the core of tests at the confirmation levels.

Teratogenicity research is focused on improving standardized tests, developing a defensible means of extrapolating test data to form a reasonable estimate of potential risk to humans, and developing a testing framework to detect functional deficits that may only appear postnatally. Developmental toxicology research will continue to develop acute and subchronic screening procedures as well as other reproductive approaches for use in regulatory programs. The applicability of these tests to risk in humans will be an important consideration.

Work in the neurotoxicology program will focus, as it has over the past few years, on systematic investigation of neurotoxicity, particularly on the development of short-term tests capable of indicating neurological change. Because there are already sophisticated techniques (behavioral neurophysiological, neurochemical, neuropathological) to detect and quantify neurotoxicity, emphasis is being placed on standardization of testing procedures and their interpretation so that quality is assured.

Mutagenesis research is involved with:

- development and validation of tests for detecting and confirming potential mutagenicity, particularly those tests that can demonstrate a chemical's mutagenicity in human and animal germinal tissues;
- the involvement of environmental chemicals in the production of aneuploidy and other chromosomal alterations in humans. The research into the distinctions between these genetic changes will improve the methods used to evaluate risk extrapolation and will considerably alter the estimation of the level of risk associated with a chemical; and
- the development, use, application, and interpretation of risk assessment methodology in the regulatory process.

Work in the carcinogenicity program involves the development of tests to detect toxic chemicals which can affect human cancer rates. These tests will eventually screen potentially carcinogenic chemicals for their action as tumor initiators, tumor promotors, and as complete carcinogens.

The epidemiology program conducts investigations that attempt to document the role specific chemicals play in the production of human disease. These studies often progress from simple descriptive and hypothesis-generating studies to the more expensive analytical epidemiological studies in which quantitative risk estimates are derived. Such studies serve the dual purpose of establishing the effects of specific chemicals on human populations and providing the data base for validating toxicological models by linking human monitoring data to appropriate experimental test data.

Emerging health effects research trends. In the future, several fundamental questions will be addressed in the area of health effects test development. One such area being increasingly stressed involves methods of determining the relationship between mutagenicity and carcinogenicity. Once established, mutagenicity data obtained in rapid and inexpensive mutagenicity tests of a chemical can then be more confidently used to assess the compound's carcinogenic potential.

Another focus of future testing will be on making an initial evaluation of a chemical's toxic potential by comparing the chemical's structure to the structure of known chemicals whose ability to promote toxicological effects, including carcinogenicity, has already been established. One currently developing trend that is also expected to continue into the future is the use of *in vitro* tests for the initial screening of chemicals. Additionally, considerable efforts are being directed to the assessment of the relationship of short-term *in vivo* biochemical and pathological effects that can predict long-term effects of certain chemicals such as carcinogens. These trends reflect the previously used time-consuming and costly nature of extended animal studies.

Researchers within the health effects laboratories are examining the metabolism of chemicals in different test systems as a means of improving the ability to qualitatively and quantitatively extrapolate test system data to man. In one project, direct comparison between the amount and type of metabolites formed in cultured animal cells is being compared with that observed in cultured cells derived from humans. A second project is studying the relationship between mutagenic response and/or cell transformation rates in four mammalian cell systems to determine if a consistent level of DNA adducts or a particular adduct is observed with the same degree of biological response. A third project is examining the utility of using the alkylation of hemoglobin by chemicals to directly compare the systemic level of active metabolites in human epidemiology studies and animal studies.

Environmental Effects Research

The current focus of environmental research is on scientific support for developing reliable test rules and standards, exposure assessment methodologies, and schemes to test the ecological effects and fate of chemicals. Research in the environmental area is currently being highlighted by the development and validation of single-species bioassays. This is being accomplished via round-robin testing in a number of different laboratories. In addition, mathematical models are being developed which are capable of integrating chemical fate with information on production, use, and disposal and environmental characteristics to provide probable environmental partitioning of given chemicals along with estimates of their environmental exposures. Models being developed include those to predict the concentrations of chemicals in air, surface waters, subsurface waters, sediments, and multi-media environments. Also, ORD is developing a model to define the movement and concentration of chemicals in the food chain and to measure human exposure to toxic chemicals present in the environment. In addition, ORD will develop, improve, and evaluate a variety of mathematical models designed to estimate the environmental effects of specific chemicals.

Another important focus of the environmental research program lies in the development of model ecosystems and experimental methods to be used to validate mathematical models such as the octanol water partition coefficient and to develop methods for simulating the fate and effects of chemicals. Physical models are currently being developed to predict the bioaccumulation and concentration of chemicals in food chain systems.

One notable result of the environmental research program to date was the FY 1980 development of an Exposure Assessment Model—EXAMS—for predicting the concentration of toxic chemicals in freshwater systems. Also developed and presently being validated via round-robin testing are several single species bioassays for defining the toxicity of chemicals to aquatic species.

One major area of research is chemical structure-activity relationships. This concept involves the establishment of correlation between the environmental fate or effects of chemicals, and their structural parameters and physical-chemical properties. Once this correlation is established, the environmental fate, behavior, and toxicity to aquatic and terrestrial species of a new chemical can be predicted based on the chemical's structure and physical-chemical properties.

Emerging environmental program research needs. The use of aquatic bioassay systems in testing is growing in importance as an environmental program research tool. The advantages afforded by the use of aquatic systems are their applicability, their cost relative to mammalian bioassays, and the fact that they may be applicable to detecting unknown water-borne carcinogens and mutagens that are not easily studied in mammals.

The development of adequate terrestrial models for fate and effects studies still is of primary importance. Predictions by mathematical models of the environmental fate of chemicals depend heavily on valid test systems in this latter area.

Monitoring Research

Toxic substances can enter the environment at the source of production, and/or during product use, transport, and disposal. Monitoring is used to help identify which of these entry points, if any, should be controlled and to determine the extent of control needed. Once a control strategy is adopted, monitoring is used for enforcement. Finally, monitoring is used to assess the effectiveness of the regulatory strategy chosen.

The objectives of current monitoring research are to identify toxic substances, to determine the extent to which they are present in the environment, and to evaluate how effective TSCA regulations are in their control. To meet these objectives, an analytical methods development and field monitoring program with associated quality assurance research has been established.

Analytical methods development research involves development of:

- methods to analyze for pollutants on a media- or matrix-specific basis (i.e., in water, air, sediment, or biological matrix);
- continuous and grab sampling methods by biological matrix (i.e., tissue, blood, etc.), medium, and pollutant;
- improved quality assurance techniques; and
- techniques that make possible identification and quantification of a wide range of pollutants by a single method.

The field monitoring program is designed to:

- evaluate and improve newly developed monitoring techniques;
- develop standardized sampling protocols for specific pollutants or classes of pollutants in all media;
- develop standardized procedures and protocols for field validation of predictive models; and
- estimate the pervasiveness of toxic substances in the environment.

During FY 1980, significant advances were made in the field testing of various components of an integrated exposure monitoring approach in southeast Ohio. A standard method for analyzing PCBs in oil was also provided to support enforcement activities, and a sampling protocol for bulk asbestos was developed and implemented to aid the Agency in its schools sampling efforts.

Emerging monitoring program research needs. With the growing reliance on predictive models in the regulatory process, it becomes essential that such methods be validated by field data to assure that the predictions do in fact reflect what actually occurs in the environment. A significant step towards meeting this need was taken in late FY 1980 with the review of a draft guideline that outlined the factors to be considered in the design of monitoring programs to either validate or apply various predictive stream models. This guideline is to be the first in a series of more specific guidelines aimed at standardizing field programs for validating different types of predictive models which may be developed in future years. Such guidelines should assure that data of known precision and accuracy will be collected during model validation studies.

In the future, as the program moves more and more into the implementation phase, the overall need for quality assurance research and support will become increasingly important. To meet this increasing need, the current project-by-project response to quality assurance requirements will be expanded in future years to provide for an ongoing base quality assurance program specifically directed at meeting the TSCA needs. This program will support research to develop standardized methods, to develop and provide reference material, and to perform audits and provide quality assurance advice and assistance as needed.

Environmental Engineering and Technology Research

The main thrust of the environmental engineering program is developing control technologies for minimizing the hazard or risk to the environment posed by toxic substances. To this end, chemical products suspected of emitting such substances are analyzed to define the modes, physical form, and extent of these substances in the chemical product and the points within a chemical product's life cycle when they are generated and released. Since this analysis also provides a basis for assessing and controlling human and environmental exposures to products of concern, it is essential to a sound toxics research program.

Emerging environmental engineering research trends. In the past, environmental engineering research has focused primarily on providing short-term technical support (toxics cleanup) rather than on long-term technology control development. Recently, however, this focus is changing and the program is adopting more long-term research direction, seeking, of note, to establish a comprehensive control technology data base for the future analysis of a broad spectrum of environmental concerns related to chemical product manufacture and use. This new orientation, it is expected, will significantly augment the program's ability to support TSCA regulatory goals.

CHEMICAL TESTING AND ASSESSMENT RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Effects	Develop methods for detecting adverse effects of neurotoxic agents	△△	△	△	△	
	Develop test methods to evaluate effects of toxic substances on perinatal health and to assess teratogenic potential	△△		△	△	
	Conduct initial evaluation of a carcinogen testing matrix (CTM) approach		△		▲	
	Establish model bioassay systems that can be used to assess carcinogenic and/or mutagenic risk	△	△		▲	
	Test hemoglobin alkylation as an integrating human dosimeter of chemical carcinogens and mutagens	△	▲			
	Develop and validate short-term bioassay methods for evaluation of oncogenic and/or mutagenic hazards	△		△	△	
Environmental Effects	Report on chemical structure as a basis for predicting microbial degradation	▲				
	Develop structure-activity concept for defining fate and effects in terrestrial environments		▲			
	Develop structure-activity concept for two classes of chemicals for predicting effects on aquatic species	△	▲			
	Develop models to predict bioaccumulation of chemicals in plants and animals in terrestrial environments		□			
	Develop methods and test protocols for defining toxicity for fish and invertebrates	▲	○			
	Develop and validate methods to evaluate effects of toxic chemicals on nitrogen flux in terrestrial soil, plants, and animals	△	○			
	Develop methods for assessing contaminated sediment and water impact on benthic crustaceans and polychaetes		▲			
	Study comparative toxicology and method of effects of selected compounds on growth and reproduction for two species of mysid shrimp	▲				
	Develop, validate, and apply *in vitro* cell methods to detect genetic toxicity in environment	▲				
	Develop mathematical exposure assessment models for predicting concentration of toxic chemicals in groundwater	△	□			
	Improve EXAMS based on laboratory and field evaluation results, and through inclusion of additional transport, transformation, and degradation process	△	□			
	Evaluate models to estimate human exposure to toxics in air	▲				

▲ *Final report, manual or user's guide;* △ *Interim report or manual;* ● *Prototype equipment and report;*
★ *Interim or final criteria formulations;* ○ *Final protocol;* ■ *Continuing effort;* □ *Other, self-explanatory*

CHEMICAL TESTING AND ASSESSMENT RESEARCH PLAN

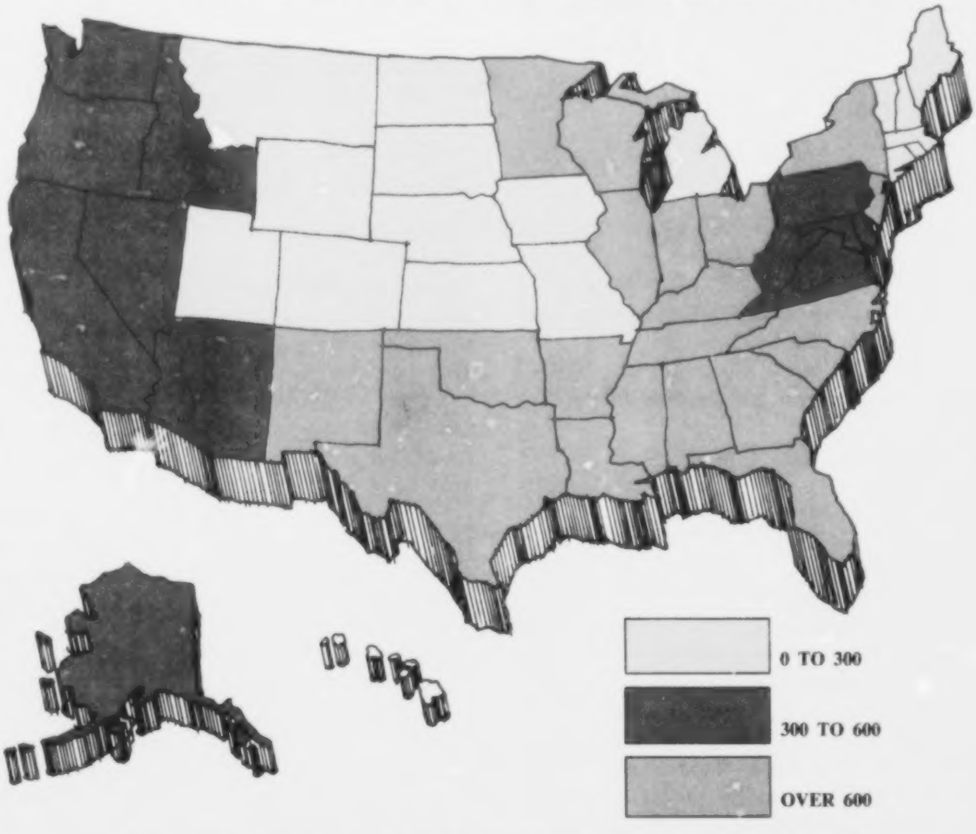
PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Environmental Effects	Develop and utilize microcosm and mathematical models for interpretation/extrapolation of results to estuarine environmental conditions			□		
	Describe intermedia transfer coefficients for the development of multimedia models	▲				
	Conduct preliminary evaluation of modular food chains			▲		
	Evaluate human exposure to contaminated Great Lakes fish	△	▲			
	Develop improved experimental aquatic ecosystem for evaluating and validating exposure models and for predicting fate of chemicals	□	▲			
	Develop freshwater microcosms for fate and ecological effects of toxic substances	△		□		
	Develop simple aquatic microbial ecosystem for screening toxic materials	△	○			
	Develop estuarine laboratory microcosms as verification tools for transport and fate				●	
	Develop leaching protocols for chemicals in soils	▲				
	Develop quantitative methods for anaerobic microbial degradation of chemicals	▲				
	Determine effect of humic substances on rate constants for hydrolysis, photolysis, and microbial degradation	△	▲			
	Complete round-robin validation and report recommendations for fathead minnow embryo-larval test	▲				
	Validate chronic toxicity using fathead minnow round-robin test	▲				
	Validate midge tanytarsus tests using round-robin tests	▲				
Monitoring	Develop monitoring guidelines for field validation of transport and fate models	▲	▲			
	Develop monitoring systems for integrated exposure assessments	△		▲		
	Develop new substrates for sampling of polar compounds			▲		
	Demonstrate droplet detector for high-pressure liquid chromatography		▲			
	Develop manual for comprehensive analysis of volatiles in soils, sediments, and sludges			▲		
Control	Develop support evaluations of pre-manufacturing notifications and engineering analysis of certain hazardous activities					■
	Develop research capabilities to meet long-term implementation time frames					■

SOLID WASTES

Public concern over the threat hazardous wastes pose to health and safety is relatively recent. Unfortunately, environmental research and development studies did not anticipate the problems in managing the hazardous residuals of our technological society, therefore that concern cannot begin to be assuaged until a library of information or proven concepts is established for decision making. To obtain the necessary information, prove the concepts, and deal with the problem in general, the legislative mandates and administrative programs are just now being defined. In the near future, EPA will concentrate on two specific facets of the hazardous waste challenge. First, a national strategy was set in motion for managing the estimated 57 million tons of hazardous waste that our society produces each year. Second, existing problem sites that degrade or threaten public health and sensitive ecosystems, and that may number as many as 2,000 in the United States, must first be carefully investigated and then corrected to reduce their hazards.

The 1976 Resource Conservation and Recovery Act (RCRA P.L. 94-580) is the federal government's comprehensive legal framework governing solid waste management. It requires the establishment of a strict program to monitor and regulate hazardous wastes from generation through transport or processing to ultimate disposal or reclamation as commercial products. The federal regulatory approach to this complex task is now being defined and many of the important technical concepts—e.g., evaluating state-of-the-art disposal practices and establishing the hazardous nature of specific industrial wastes—were initially addressed in 1980.

In December, 1980, the President signed the Comprehensive Environmental Response Compensation and Liability Act of 1980 (P.L. 96-510), commonly referred to as "Superfund." The objectives of the legislation are to provide authorities with the means to: respond to release of hazardous waste from inactive hazardous waste sites which endanger public health and the environment, establish a hazardous waste response fund from a system of fees, establish prohibitions and requirements concerning inactive hazardous waste sites, and provide for liability of persons responsible for release of hazardous waste at such sites.



GEOGRAPHIC DISTRIBUTION OF UNCONTROLLED SITES

ESTIMATED NUMBER OF UNCONTROLLED SITES PER EPA REGION

The new law establishes a five-year, $1.6 billion fund to be obtained from special industrial assessments and general revenues.

The Environmental Protection Agency will administer a broadly ranging program of remedial actions funded either by these Superfund resources or by parties responsible for hazardous conditions at improperly operated sites. For implementation, this program will need sound conceptual approaches and technical information for site assessment, site worker safety, evaluation of the cost and likely effectiveness of alternative remedies, evaluation of damage resulting from the conditions of the site, and estimation of the risks that remain after remedial measures.

The research and development programs in support of both the RCRA and Superfund legislation will be principally designed to fulfill the near-term needs of EPA's regulatory programs. Limited experience in dealing with hazardous waste problems has created an immediate and pressing need for EPA to develop the concepts and to assemble the technical data that will support the policies and regulations of these two laws.

RESOURCE CONSERVATION AND RECOVERY

The major research areas under the Resource Conservation and Recovery Act are:

- identification and risk characterization of hazardous wastes generated by industrial processes and commercial product use; and
- characterization of the cost and capabilities of destruction, treatment, and disposal of hazardous wastes.

The first research area supports the Agency in formulating regulatory approaches and making specific decisions to designate waste materials as hazardous. EPA's policy for identifying specific wastes as hazardous relies upon objective criteria for physical parameters, i.e., flammability, corrosivity, and reactivity; however, satisfactory criteria for objective measures of toxicity are not available. For the most part, EPA uses a case-by-case review of specific wastes to determine whether they should be deemed hazardous on the basis of the known toxicity of their chemical constituents. Research topics to establish a comprehensive means to make the proper designations include process engineering analysis of waste generation, assessment of chemical component toxicities, and assessment of the environmental mobility and persistence of chemical constituents. A strong research component on monitoring systems and quality assurance is vital to the success of this program, which requires valid data, obtained by standard sampling and analytical methods to support the investigation of hazardous waste sites.

The second research area supports the Agency's permit review process that is based upon evaluations and engineering judgments of environmentally acceptable best available technologies for hazardous waste treatment, destruction, and disposal. However, because of the lack of information about the commercial technologies, such as incineration and land disposal, EPA has been unable [illegible] regulations based upon the techn[illegible] specifications. The research progr[illegible] therefore specifically designed to assure that the permits require disposal facilities to generate information on their performance and that all reliable technical information is available when case-by-case permit decisions are made. This information, in conjunction with data derived from research facilities, will allow progress toward establishing the performance requirements for incineration and land disposal facilities.

Identification of Hazardous Wastes for RCRA

High-quality data to identify hazardous waste characteristics are crucial to the effective and economical management of harmful wastes. Hazardous waste identification has today come to encompass the whole set of processes concerned with proper sampling, analysis, measurement, and data-quality assurance of hazardous wastes. The development of valid identification protocols that use these processes is vital, but our current knowledge about many of the processes is incomplete.

Chief among the short-term (FY 1981) research needs is developing a means of identifying and characterizing hazardous waste streams. Specifically, research will develop protocols for engineering analysis of the many industrial processes that can produce hazardous wastes, and will prescreen the process chemistry to predict the occurrence of toxic materials.

The engineering analysis method determines the probability that hazardous substances are being generated in among the thousands of industrial waste streams currently being produced. The analysis evaluates the industrial process that is the source of the waste and determines through application of chemical reaction rate theory and kinetics whether

SHORT, MEDIUM, AND LONG-TERM RESEARCH NEEDS IN RESPONSE TO THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

Research Categories	Hazardous Waste Identification				Hazardous Waste Technology			Hazardous Waste Effects		High Volume Wastes		Non-Hazardous Wastes	
Research Areas RCRA Programs	Quality Assurance	Waste Characterization	Abandoned Facilities Response	Pollution Migration and Retention in Soils	Treatment	Thermal Decomposition	Containment	Health Effects	Transport and Fate	Mining	Electric Utility and Fuel Processing	Municipal Solid Wastes	Waste-as-a-Fuel
Section 1000: Guidelines	***	***	***	*	**	**	**	*	*	*	*	**	*
Section 2003: Resource Recovery and Conservation Panels	NA	NA	NA	NA	*	NA	NA	NA	NA	NA	NA	**	**
Section 3001: Identification and Listing of Hazardous Waste	***	***	NA	NA	NA	NA	NA	*	NA	**	**	NA	NA
Section 3002: Standards Applicable to Generators of Hazardous Wastes	***	***	NA[1]	*	***	***	***	*	*	*	*	NA	NA
Section 3003: Standards Applicable to Transporters of Hazardous Wastes	NA	***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Section 3004: Standards Applicable to Owners & Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.	***	***	NA[1]	*	***	***	***	*	*	*	*	NA	NA
Section 3005: Permits for Treatment, Storage, or Disposal of Hazardous Wastes.	***	***	NA[1]	*	***	***	***	*	*	*	*	NA	NA
Section 3007: Inspections	***	***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Section 3008: Federal Enforcement	***	***	***	**	***	***	***	**	**	NA	NA	NA	NA
Section 3010: Effective Date	***	***	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Section 4002: Federal Guidelines for Plans	NA	**	NA	NA	NA	NA	NA	NA	NA	NA	NA	**	*
Section 4004: Criteria for Sanitary Landfills	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	***	NA
Section 4005: Upgrading of Open Dumps	NA	NA	**	*	NA	NA	NA	*	**	NA[2]	NA[2]	**	NA
Section 7003: Imminent Hazard	NA	***	***	**	**	*	*	*	**	NA	NA	NA	NA
Section 7007: Grants or Contracts for Training Projects	*	*	*	*	*	*	*	*	*	*	*	*	*
Section 8001: Research Demonstrations, Training and Other Activities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Section 8002: Special Studies	NA	NA	NA	NA	NA	NA	NA	NA	NA	**	NA	***	NA
Section 8003: Coordination, Collection, & Dissemination of Information	NA	***	***	*	**	**	*	*	*	*	*	*	*
Section 8004: Full-Scale Demonstration Facilities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Section 8005: Special Study & Demonstration Projects on Recovery of Useful Energy & Materials	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*	*
Section 8006: Grants for Resource Recovery Systems and Improved Solid Waste Disposal Facilities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*	*

Note: All research products are intended for use by federal, state and local governments.
Also Note: All research, development, and demonstration pertaining to hazardous wastes will take place at federal facilities or on federal lands.

LEGEND:

1. Short term need if generator is responsible or proven responsible for abandoned site.
2. Unless open dump is associated with a mine.
NA Not Applicable

* Long Term
** Medium Term
*** Short Term

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waste streams produced are likely to contain hazardous components. Although the engineering analysis method is less precise for identifying hazardous wastes than is sampling and chemical analysis, it provides a screening method for analyzing large numbers of waste streams. It also allows the use of effective sampling and chemical analysis schemes that are most likely to identify and measure the important hazardous components in the waste.

The engineering analysis method requires the development of information on the generic types of chemical reactions used industrially—chlorination, ammoniation, hydrolysis—and the feedstocks used commercially. An understanding of the unit process

SHORT, MEDIUM, AND LONG-TERM RESEARCH NEEDS IN RESPONSE TO THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

NON-HAZARDOUS WASTES

RESEARCH AREAS / RCRA PROGRAMS	RESEARCH CATEGORY: Non-Hazardous Wastes						
	Land Disposal				Resource Recovery	Energy	
	B.A.T. for Accelerated stabilization.	Gas & Leachate Formation Studies	Codisposal	Manual of Practice (Site Selection, Design, Operation and Closure)	Material Technology Development	Technology Development	Pollution Assessment & Control
Section 1008: Guidelines	*	**	**	**	*	*	*
Section 2003: Resource Recovery and Conservation Panels	NA	**	*	**	**	**	**
Section 4002: Federal Guidelines for Plans	NA	**	*	**	*	*	*
Section 4004: Criteria for Sanitary Landfills	**	*** 1	**	**	NA	NA	NA
Section 4005: Upgrading of Open Dumps	**	**	**	**	NA	NA	NA
Section 6002: Federal Procurement	NA	NA	NA	NA	*	NA	NA
Section 7003: Imminent Hazard	**	**	*	NA	NA	NA	NA
Section 7007: Grants or Contracts for Training Projects	*	*	*	*	*	*	*
Section 8001: Research Demonstration, Training & Other Activities	*** 1	*** 1	*** 1	**	*	*	*
Section 8002: Special Studies	NA	NA	NA		***	*	NA
Section 8003: Coordination, Collection, & Dissemination of Information	*** 1	*** 1		*** 1	*	*	*
Section 8004: Full-Scale Demonstration Facilities	*	*	*	NA	*	*	*
Section 8005: Special Study & Demonstration Projects on Recovery of Useful Energy and Materials	NA	NA	NA	NA	**	**	NA
Section 8006: Grants for Resource Recovery Systems & Improved Solid Waste Disposal Facilities	*	*	*	NA	*	*	*

LEGEND:

NA	Not Applicable
*	Long Term
**	Medium Term
***	Short Term
1	All outputs will be completed during FY 80.

REPRESENTATIVE HAZARDOUS SUBSTANCES WITHIN INDUSTRIAL WASTE STREAMS

INDUSTRY / HAZARDOUS SUBSTANCES	Arsenic	Cadmium	Chlorinated Hydrocarbons	Chromium	Copper	Cyanides	Lead	Mercury	Miscellaneous Organics	Selenium	Zinc
Mining & Metallurgy	X	X		X	X	X	X	X		X	X
Paint & Dye		X		X	X	X	X	X	X	X	
Pesticide	X		X			X	X	X	X		X
Electrical & Electronic			X		X	X	X	X		X	
Printing & Duplicating	X			X	X		X		X	X	
Electroplating & Metal Finishing		X		X	X	X					X
Chemical Manufacturing			X	X	X			X	X		
Explosives	X				X		X	X	X		
Rubber & Plastics			X			X		X	X		X
Battery		X					X	X			X
Pharmaceutical	X							X	X		
Textile				X	X				X		
Petroleum & Coal	X		X				X				
Pulp & Paper								X	X		
Leather				X					X		

reactions will allow prediction of the waste chemicals likely to be created, while an understanding of the separation or purification process—distillation, solvent extraction, stripping—will allow prediction of the likelihood that a particular chemical will be found in specific waste streams. By then integrating the understandings of unit reactions and separation processes with flow sheets of actual processes, very important insights can be gained into the likely occurrence and composition of hazardous wastes in manufacturing.

For identifying hazardous wastes by screening waste samples, future biological monitoring and bioassay techniques may be effective and less expensive than chemical analyses. If successful, these techniques may become objective measures of waste toxicity. Biological monitoring techniques will also be evaluated for use in developing exposure-assessment guidelines, a key element in the risk assessment process. The biological monitoring and assay techniques will require considerable research and testing before being available for use in screening waste samples for the presence of toxic and hazardous components.

Hazardous Waste Risk Assessment

The paramount objective of EPA in the management of solid and hazardous wastes is to protect public health from the effects of these substances—effects produced either directly or by transmission through the environment. In order to accomplish this objective, EPA must have reliable tools to gauge the potential impacts of various substances under a variety of circumstances. The purpose of the hazardous waste risk assessment program is to assess the toxicity of wastes and the likelihood that toxic components will prove to be chemically stable but physically mobile enough in the environment to reach people or ecosystems. The important aspects of the risk assessment are the interpretation of toxicological information and the establishment of the likelihood that substantial exposure will derive from improper disposal methods.

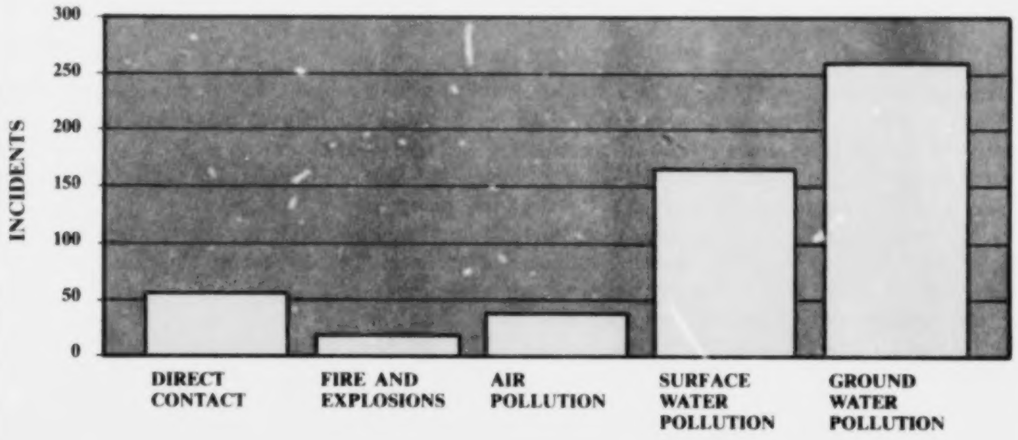
The research strategy for risk assessment includes:

- the production of risk assessment documents for specific chemicals (scientific assessment);
- determination of toxic effects on humans likely to result from exposure to hazardous wastes;
- development of methods and data to define environmental transport and fate characteristics of hazardous wastes;
- determination of likely ecological effects of environmental insult from hazardous wastes;
- development of socioeconomic criteria and model scenarios of the impacts to be expected for various waste management incidents or disposal methods.

Scientific assessments will provide three kinds of activities and outputs: qualitative and quantitative cancer and mutagenic risk assessments, health effect profiles for hazard evaluation of specific chemicals, and exposure assessment guidance for use as hazard evaluation. Outputs in FY 1981 will include: (1) qualitative cancer assessment documents for five chemicals, (2) hazard profiles of health and aquatic effects for 150 chemicals, (3) exposure scenarios to mesh with health profiles, and (4) technical assistance for enforcement actions. Efforts in all these areas are expected to increase in the near term.

The health effects research effort is concentrating on the development of bioassay techniques to screen wastes or waste leachates leaving sites. Near-term research in this area will concentrate on the development of an animal neonatal test system for growth and organ system functions. Relative risk evaluation procedures will also be developed with efforts centering on animal studies of chemical carcinogens in the bloodstream. Biological studies will concentrate on development of test procedures for evaluating the effects of exposure to hazardous wastes. Research will apply the screening tests to actual complex mixtures of hazardous wastes.

EPA's research into how hazardous contaminants move and change through subsurface transport will develop groundwater investigation methods, study waste mobility characteristics, determine subsurface factors affecting mobility, and devise predictive models. Hazardous waste disposal sites with different hydrogeologies will be chosen for intensive study. A report will be published describing protocols for



DAMAGE INCIDENTS AT 421 UNCONTROLLED WASTE DISPOSAL SITES developing hazardous waste mobility screening models. Field tests will also be conducted to characterize waste constituents and correlate mobility information with the findings from laboratory studies. Permeability, soil morphology, and biological degradation will be included as parameters in developing mathematical models for hazardous waste transport and transformation in saturated and unsaturated areas of groundwater.

The research into surface water transport and fate is an important area of research. Along with other exposure assessment methods, the Exposure Analysis Modeling System (EXAMS) will be adapted to predict concentrations through surface and shallow subsurface hazardous waste exposure pathways. General chemical environmental exposure assessment capabilities will be applied to develop models to design and evaluate hazardous chemical disposal management scenarios.

The risk assessment research planned in FY 1982 will address the impacts of hazardous wastes upon terrestrial and aquatic ecosystems. Activities will be directed toward:

- adaptation and development of techniques for assessing ecological damage from disposal of hazardous wastes and their potential entry into the food chain;
- development of methods for measuring the bioenvironmental stress of hazardous wastes, which can also be used for detecting and evaluating sites;
- development of criteria to be used in evaluating remedial action alternatives for aquatic and terrestrial organisms for organic chemicals found in hazardous waste leachates;
- development of protocols for using selected aquatic organisms as surrogate tests for human toxicity;
- development and refinement of a chemical model for calculation/prediction of the bioavailability of toxic metals in hazardous wastes; and
- adaptation of methods for using introduced organisms to detect environmental stresses from hazardous waste disposal sites.

Hazardous Waste Measurement for RCRA

A systematic plan has been developed to implement the research and development required for the Agency's hazardous waste monitoring program. The three basic areas in this program are:

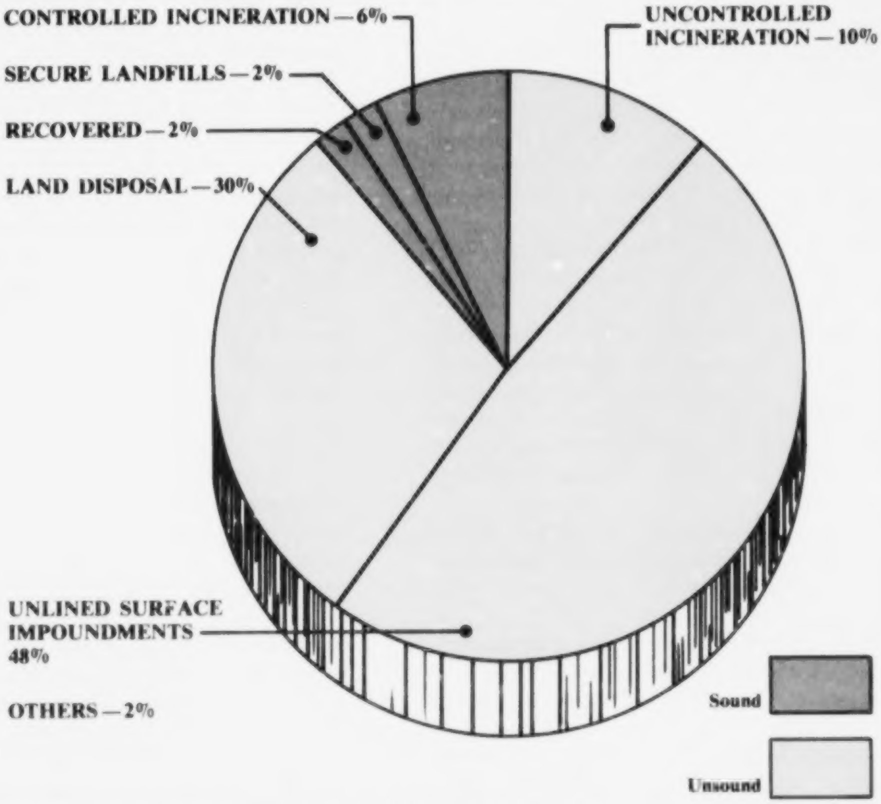
1. Quality assurance. The basic element in producing sound defensible data in any monitoring effort is a good quality assurance program. The technical approach provides immediate response using "best available methodology." It also allows for the identification of gaps or deficiencies in available methodology (unavailable or inadequate methods) and for the research required to correct those inadequacies that limit the quality of data being produced in current monitoring efforts. This approach will ultimately provide an improved monitoring program that is based upon validated methodology of known accuracy and precision.
2. Monitoring methodology. This program area provides development, improvement, and evaluation of the methods required for hazardous waste monitoring. The evaluation data will be used to validate the acceptability of the methods as standard/equivalent methods for the quality assurance program. Once validated, this methodology will be included in the guidelines provided for hazardous waste monitoring.
3. Monitoring guidelines. Guidelines are required to assure adequate, consistent, and cost-effective monitoring in all hazardous waste efforts. The technical approach provides immediate response with "interim" guidelines based upon available methodology and the current knowledge of the requirements. As the interim guidelines are tested and the hazardous waste problems become better defined, improved guidelines will be developed, tested, and provided.

Hazardous Waste Engineering and Technology for RCRA

Since RCRA has eliminated the environmentally unsafe options for disposal of hazardous wastes, those who generate the wastes must turn to other alternatives. Improved treatment and disposal technology is necessary if hazardous materials are to be managed in a manner that is economically as well as environmentally sound.

Five major areas have been identified for priority research in hazardous waste technology:

- development and field verification of guidelines for site selection, design, operation, and control of land disposal facilities;
- testing and evaluation of technologies for physical, chemical, and biological treatment of hazardous wastes;



HAZARDOUS WASTE DISPOSAL PRACTICES

- development of thermal destruction techniques to include design criteria and maintenance procedures for effective systems;
- evaluation of concepts for centralized hazardous waste treatment and disposal facilities; and
- continuation of support to the various EPA programs with hazardous waste responsibilities.

EPA recognizes that thorough study of all hazardous waste streams and potential treatment and disposal technologies is not feasible. EPA will, therefore, concentrate its short-term efforts on areas of acute need that industry research will not be sufficient to meet.

Short-term research efforts for waste destruction will focus on incineration. Data are required for "best engineering judgments" in designing, operating, and reviewing incineration facilities. Protocols for incinerator trial burns will be developed and verified, and field tests of incinerators will be conducted in order to accumulate data on the effectiveness of combustion controls and technology for elimination of air contaminants. Research will also concentrate on improving incinerator design and operation procedures, developing and verifying sampling processes, and improving analytical methods for measuring and controlling incinerator performance. The destruction capability and environmental acceptability of co-firing of hazardous wastes into high-temperature industrial processes, such as cement kilns and process heaters, will also be studied. In the long term, advanced thermal oxidation technologies such as molten salt and fluidized bed incinerators, wet oxidation, and instrumentation for and automation of incinerators will be evaluated. The incineration program will also evaluate present and proposed air pollution control concepts.

Disposal facilities research in the short term will address the development of manuals on engineering and environmental aspects of hazardous waste disposal through land treatment and in landfills and surface impoundments. Land treatment will be studied to assess the impact of a variety of hazardous waste streams.

The need to estimate the post-closure care period for monitoring and prevention of adverse effects from closed hazardous waste surface impoundments, land treatment, underground injection, and landfill facilities has also been identified as a problem warranting priority research. Improved methods for estimating and controlling releases of hazardous components and an improved protocol for accounting for soil/waste interactions in estimating long-term adverse effects need to be developed. Furthermore, because the periods of potential problems from these facilities often extend beyond the financial responsibility provisions under RCRA, there is an acute need for improved methods to accelerate stabilizing, or rendering to non-hazardous condition, the waste in completed sites.

Volatile releases from hazardous waste management facilities also require a variety of research needs, including: (1) improvements in procedures and protocols for estimating the release of volatiles from liquid to air and for evaluating the impacts of volatile releases from surface impoundments, and (2) development of methods for controlling the release of unacceptable volatiles.

In the overall program, a major medium-term research effort will be the collection of data on performance, economics, waste stream compatibility, energy efficiency, capacity, and operating conditions of various technologies as a function of industrial waste streams. This work will be closely coordinated with the process engineering analysis and industrial hazardous waste survey programs, which will begin to more accurately identify the sources, quality, quantity, and disposition of currently generated waste materials.

Although most of the engineering and technology program is devoted to incineration and land disposal, a small program will be maintained in alternative waste treatment technologies. These programs will evaluate the costs, performance, and potential risks of technologies that reclaim commercial products from hazardous wastes. The areas of research have not been fully specified, but candidates include chlorination and dechlorination chemistry, demetalization of oils and aqueous wastes, carbon regeneration, and supercritical fluid separation processes.

Energy and Mineral Wastes for RCRA

Because certain industrial and mining operations yield large volumes of waste that may contain hazardous constituents, EPA created a special category to deal with them. Included in this category are: uranium mining wastes; phosphate mining, milling, and

SPECIAL WASTES
(Metric ton / yr)

WASTE	QUANTITY	POSSIBLE HAZARD
Cement Kiln Dust	12 million*	Alkalinity and heavy metals
Utility Waste (fly ash, bottom ash, scrubber sludge)	66 million*	Heavy metals (trace)
Phosphate Mining, Beneficiation, and Processing Waste	400 million	Radioactivity (low levels)
Uranium Mining	150 million	Radioactivity
Other Mining Waste	3 billion *	Heavy metals, acidity
Gas and Oil Drilling Muds and Oil Production Brines	5 million*	Alkalinity, heavy metals, toxic organics, salinity

Note: It is not yet known how much of the total quantity of waste marked with an asterisk (*) is, in fact, hazardous waste.

processing wastes; certain other mining wastes; cement kiln dust; utility wastes, i.e., coal ash and flue gas desulfurization wastes; and gas and oil drilling muds and brines. Legislation temporarily exempts some of these high-volume wastes from regulation as hazardous wastes. The legislation, called the "omnibus special waste amendments" to RCRA, will require extensive studies of these wastes, including investigation of:

- their sources, volumes, characteristics, and locations;
- present treatment, storage, disposal, and utilization practices;
- potential dangers to human health and the environment from their treatment, storage, disposal, and reuse;
- cases in which their danger to human health or the environment has been proven;
- alternatives to their current treatment, storage, and disposal methods;
- costs of such treatment, storage, and disposal methods and various alternatives;
- impacts of such alternatives on the use of the materials and other natural resources;
- current and potential utilization of such wastes; and
- wastes from geothermal energy development.

Efforts to address many of these topics for utility wastes are already under way. In late 1979, a multimillion dollar program was initiated to obtain field data on disposal of wastes from coal-fired electric generating plants. At least 12 disposal sites are being monitored with sampling of waste, underlying soil, groundwater, leachate, and runoff/surface water to estimate environmental effects and costs of disposal. The remaining efforts required by the RCRA amendments will be initiated in early FY 1981. All of these studies should be completed by late FY 1982. Results are expected to require more modest follow-up projects.

Like the utility waste studies, mineral waste research to address the questions raised by the RCRA amendments was initiated in late FY 1979. These studies have concentrated on uranium mining wastes, phosphate mining and beneficiation waste, and wastes from seven selected ore mining industries (copper, iron, lead, molybdenum, silver, gold, and zinc). Investigations of various waste management practices currently in use for waste rock, overburden, low-grade ore, tailings, milling wastes, and sludges from treatment and processing plants have been included. Detailed sampling and analysis of surface water, groundwater, and air will be conducted at 10-20 mining-related solid waste disposal operations. The results from these studies will provide the required input for the developments of rules and regulations as specified by RCRA.

Assessments to determine the hazards of gas and oil drilling muds and brines should begin late in FY 1981. Geothermal drilling muds and brines will also be studied. To support anticipated growth in the use of geothermal sources, full-scale studies are anticipated for FY 1983-1985 on residual sludges resulting from injection pretreatment, control technologies for hydrogen sulfide emissions, and other factors.

Lysimeter studies of oil shale leaching which have already yielded valuable data on disposal of spent shale, will continue in the short range. Oil shale ignitability will also be investigated, and an effort will be made to develop regulations governing coal liquefaction and gasification. Management guidelines will also be developed for gasohol production wastes.

COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION AND LIABILITY ACT

New legislation has given EPA the responsibility, authority, and resources for an aggressive program to repair poorly operated waste sites that now pose a threat to public health and the environment. Previously, research resources had been used to support the Agency's program to compel responsible parties to remedy the threat of such sites. With the new law, EPA has a greatly changed need for sound technical concepts and information for a responsible use of legislative authority. The research areas have not been fully defined nor a program developed to supply the necessary data; however, some of the technical issues raised by Superfund are clear and research strategies will be developed in the near future. The major areas for policy decisions include:

- Superfund creates a new agency with the Public Health Service of the Department of Health and Human Services—the Agency for Toxic Substances and Disease Registry. This agency will perform in site investigations of health conditions. EPA must develop a mechanism to insure health studies are performed in such a way that results will validate risk assessment models.

- Superfund requires EPA to define reportable quantities of material released to the environment. Although the law relates much of the concern for reportable quantities to the characteristics of the chemical industry, EPA must decide how an estimation of the likelihood of public health or environmental damage will be used in establishing reportable quantities.
- One use of Superfund will be in compensation for damage. If the compensation provisions are to be used, they must be based upon a credible rationale for determining damages. EPA must begin to develop guidelines and methods for damage assessment.
- Superfund requires a revision of the National Contingency Plan which governs the use of federal resources for mitigating problems associated with releases of hazardous substances. This revision must include a new section to be called the National Hazardous Substance Response Plan. Responsibility for developing the plan rests with the Council on Environmental Quality in concert with EPA and other participating agencies. The implementation areas to be addressed include:

1. Methods for discovering and investigating facilities at which hazardous substances have been *disposed;*
2. Methods for evaluating and remedying release or threats of releases; evaluations will include analysis of relative costs;
3. Methods and criteria for determining the appropriate extent of removal and remedy;
4. Methods for the identification, procurement, maintenance, and storage of response equipment;
5. Methods for assuring that remedial action measures are cost-effective over the period of potential exposure;
6. Criteria for determining priorities among release or threatened releases (relative risk to health or environment); and
7. Procedures, techniques, materials, equipment, and methods for removing or remedying hazardous materials.

Developing a sound measurement capability is a fundamental part of any research program. Future development of a research strategy will entail identifying and assigning priorities to the tasks required to improve EPA's knowledge in these areas.

SOLID WASTE RESEARCH PLAN

Hazardous Waste Identification

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Quality Assurance	Provide new reference "standard" materials	△	△	△	△	△
	Perform laboratory intercomparison studies and on-site evaluation	△	△	△	△	△
	Provide criteria documents for quality assurance program	▲				
	Validate sampling extraction and analytical methods		△	△	△	△
	Perform methods equivalency studies		△	△	△	△

▲*Final report, manual or user's guide;* △*Interim report or manual;* ●*Prototype equipment and report;*
★*Interim or final criteria formulations;* ○*Final protocol;* ■*Continuing effort;* □*Other, self-explanatory*

SOLID WASTE RESEARCH PLAN

Hazardous Waste Identification

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Methodologies	Develop/publish manual of "best available methods" for sampling and analysis of hazardous waste	▲				
	Identify biomonitoring requirements/approaches	▲				
	Identify field analytical methods	▲				
	Develop, improve, evaluate methodology for subsurface characterization	▲				
	Develop/improve sampling and analysis methods		△	△	▲	
	Develop/publish manual of "best available methods" for biomonitoring of hazardous waste		▲			
	Develop/evaluate field test kits		●			
	Develop/improve advanced analytical methods		△	△	△	▲
	Evaluate and field test methodology for subsurface characterization		△	△	▲	
	Develop, improve, evaluate biomonitoring methods			△	△	▲
	Field test/evaluate test kits			▲		
Monitoring Guidelines	Prepare interim criteria guidelines for monitoring groundwater	▲				
	Publish interim guidelines for monitoring air	▲				
	Develop/publish interim biomonitoring guidelines	—	▲			
	Develop criteria and systems for site selection and site evaluation	—	▲			
	Publish interim monitoring guidelines manual for water		▲			
	Field evaluate monitoring guidelines for groundwater		—	▲	▲	
	Field evaluate biomonitoring guidelines			—	—	▲
	Field evaluate and publish guidelines for site selection and site evaluation			—	—	▲
	Develop and publish final monitoring guidelines for water				—	▲
RCRA Support	Evaluate Gray Iron Foundry waste	▲				
	Perform hazardous waste characterization of other industries as required			△	△	△
Uncontrolled Facilities Response	Provide remote and contact monitoring as required	—	—	—	—	■
	Provide special monitoring as required	—	—	—	—	■
	Provide quality assurance program	—	—	—	—	■

SOLID WASTE RESEARCH PLAN

Mineral and Energy Wastes

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Mineral Wastes	Characterize and design management standards for mining wastes		▲			
	Characterize and design management standards for phosphate processing wastes and cement kiln dusts			▲		
	Evaluate innovative waste handling and treatment technologies for mineral wastes				△	△
Energy Wastes	Determine design standards for management of coal ash and flue desulfurization waste		▲			
	Determine costs for utility industry compliance with RCRA performance standards		▲			
	Determine coal pile drainage effects on groundwater		▲			
	Characterize and design management standards for oil shale mining and beneficiation			▲		
	Characterize and compare electric utility coal ash and FGD waste with industrial boiler waste			▲		
	Determine design standards for management of gas and oil drilling wastes			▲		
	Characterize and design management standards for coal liquefaction gasification wastes			▲		
	Determine design standards for management of geothermal energy waste			▲		
	Evaluate innovative waste handling and treatment technologies for energy wastes				△	△

SOLID WASTE RESEARCH PLAN

Hazardous Waste Risk Assessment

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Scientific Assessment	Produce qualitative cancer assessment documents for selected chemicals	▲	—	—	—	■
	Develop hazard profiles of health and aquatic effects for 150 chemicals	▲	—	—	—	■
	Develop exposure scenarios for 150 chemicals	▲	—	—	—	■

SOLID WASTE RESEARCH PLAN

Hazardous Waste Risk Assessment

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Effects	Develop annual growth and organ system function exposure screening test and apply to complex chemical mixtures	▲	▲			
	Develop carcinogen exposure screening test based on animal hemoglobin monitoring and apply to complex chemical mixtures	▲	▲			
	Develop portable peripheral and central nervous system hazardous waste exposure monitoring system	●				
	Develop protocols for biological screening methods for potentially hazardous wastes			▲		
	Develop regulatory thresholds for required IARC and NCI known human, suspect human, and known animal carcinogens				▲	
	Validate analytical methods capable of detecting these carcinogens at the regulatory threshold				▲	
Transport and Fate – Subsurface	Adapt existing groundwater movement models to hazardous waste transport scenario	▲				
	Select two hazardous waste disposal sites and apply transport and fate model to selected sites	▲	▲			
	Develop model for hazardous waste mobility screening		▲			
	Field test waste constituents and correlate mobility information with laboratory findings		▲			
Transport and Fate – Surface	Develop and test multimedia exposure assessment screening method		—	▲		
	Design computer-based model for multimedia exposure assessment and test model at selected sites				▲	
Ecological Effects	Develop models for assessing ecological damage from hazardous waste disposal		▲			
	Develop methods for measuring bioenvironmental stress of hazardous waste		▲			
	Develop hazardous organic chemical exposure criteria for aquatic and terrestrial organisms		▲			
	Develop protocols for using selected aquatic organisms as surrogate tests for human toxicity		▲			
	Develop a chemical model for calculation/prediction of bioavailability of toxic metals in hazardous waste		▲			
Socioeconomic Effects	Develop economic criteria for waste management scenarios			▲		
	Study incentive structures for hazardous waste disposal			▲		
	Complete multimedia assessment of hazardous waste disposal on a regional basis			▲		

SOLID WASTE RESEARCH PLAN

Hazardous Waste Technology

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Predisposal Treatment	Evaluate innovative technologies for treatment of hazardous waste	△	△	△	△	△
	Assess hazardous waste recycle/reuse options	△	△	△	△	△
Thermal Destruction	Develop and verify protocols for trial incineration "burns" of hazardous wastes	▲				
	Conduct field tests of incinerators and air pollution abatement technology	△	△	△		
	Develop design criteria for hazardous waste incinerators	▲				
	Evaluate feasibility of using existing alternative combustion facilities for co-combustion of hazardous wastes in industrial processes	△	▲			
	Develop and verify means of transferring small-scale combustion test results to field-scale testing conditions and requirements. Develop a waste stream/incineration technology compatibility protocol		▲			
	Develop and validate standard sampling and on-line testing analysis procedures and equipment for monitoring full-scale test burns and for permit compliance monitoring		▲			
	Evaluate advanced thermal oxidation technologies for hazardous waste destruction			▲		
	Evaluate instrumentation and control technologies for incineration			▲		
	Develop advanced air pollution control technology for hazardous waste incineration			▲		
	Conduct pilot-scale studies of emerging improved incinerator concepts				▲	
Disposal	Develop technical resource documents for design operation and closure of hazardous waste disposal facilities	▲				
	Evaluate alternative sites for disposal of hazardous wastes	▲				
	Measure and evaluate the quality and quantity of volatile emissions from surface impoundments and landfills	▲				
	Evaluate quick indicator methods for liner/waste compatibility, permeability, durability, and protocol for comparing predicted performance of alternative liner designs			▲		

SOLID WASTE RESEARCH PLAN

Hazardous Waste Technology

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Disposal	Evaluate quick indicator tests for predicting leachability, durability, longevity, and compatibility of waste/process combinations			▲		
	Investigate advanced liner designs				▲	
	Monitor industrial activities on land cultivation of hazardous waste				△	△
	Conduct demonstration of inactive mine storage/disposal of encapsulated hazardous wastes				△	△
Resource Recovery	Develop improved technologies for forecasting quantities and composition of solid waste	▲				
	Prepare RDF for cement kiln firing	▲				
	Assess environmental effects of co-firing of waste with coal	▲				
	Evaluate resource recovery potential from hazardous and high-volume wastes		▲			
	Evaluate processes and environmental effects of full-scale resource facilities				▲	
Landfilling	Assess fate of heavy metals during landfill stabilization	▲				
	Monitor remedial site which was surface capped	▲				
	Develop a manual of practice on groundwater sampling techniques and municipal waste disposal sites	▲				
	Develop leachate production forecasting technique to guide the design, operation, and permitting constraints for specific landfill sites			▲		
	Evaluate various control methods to minimize environmental impact of landfills subject to RCRA regulations			▲		
	Evaluate various methods to stabilize landfills to minimize environmental impact				▲	

DRINKING WATER

The responsibility for maintaining safe drinking water has traditionally rested with state and local governments. Passage of the Safe Drinking Water Act (SDWA) of 1974, however, directed that the federal government share in this responsibility through the development and promulgation of national drinking water standards that would protect public health and welfare, and through the implementation of a national program to protect drinking water and groundwater.

The standards, which specify the maximum contaminant levels (MCL) allowable in the nation's drinking water supply, are of particular concern to EPA because of their kinship with other serious issues facing the Agency today—hazardous wastes definition, land treatment and reuse projects criteria, groundwater quality protection, environmentally sound waste disposal methods, and surface water quality criteria and standards.

MCLs covering bacteria, turbidity, inorganic chemicals, radionuclides, and certain pesticides have been in effect since 1977. In 1979, these were supplemented with regulations that additionally limited the amounts of chloroform and other trihalomethanes in drinking water. In the near future, MCLs for substances suspected of being carcinogens such as carbon tetrachloride and trichloroethylene will be developed by EPA.

Existing regulations will be revised to incorporate new data, the effects of drinking water additives will be addressed, and methods to control harmful contaminants—especially those that may increase the incidence of cardiovascular disease—will be defined and developed. Groundwater pollution also will receive significant emphasis through studies designed to determine the fate and transport of contaminants under a variety of soil conditions.

RESEARCH OBJECTIVES

The purpose of EPA's drinking water research program is to enhance the scientific and technical foundations that underlie National Drinking Water Regulations and all regulations that protect groundwater quality. Its objectives are to:

- identify those substances that occur in drinking water supplies with sufficient frequency to warrant regulation;
- define the effects of drinking water contamination on human health;
- establish analytical procedures to monitor contaminants;
- identify treatment processes or new treatment technologies capable of minimizing contaminant formation or reducing concentration levels; and
- develop and validate equipment and technologies for sampling and monitoring groundwater quality.

The three categories of contaminants under study are organic, inorganic (including asbestos and radionuclides), and microbiological; also being studied are methods to protect groundwater from these types of contaminants.

Organic Contaminants

In a few intensively studied drinking water supplies, over 900 organic compounds have been identified at concentrations exceeding 1 part per trillion (nanogram per liter). Interest in synthetic organic contaminants found in groundwater supplies has become especially acute in the last few years. To support regulatory decisions on these compounds, the drinking water research program is designed to provide methods to efficiently detect, identify, and monitor such organic contaminants. Additionally, the program seeks to determine human health impacts from these contaminants, as well as methods for their control and treatment. Methods for the control of treatment by-products are also addressed.

Detection, identification, monitoring. Significant attention has been given in the program to the development of analytic methods capable of concentrating, isolating, and characterizing non-volatile organic substances. Also being developed are methods to isolate non-halogenated products such as epoxides and quinones, substances formed when disinfectants (oxidizing agents) react with organic compounds already in water. An outgrowth of the program's research is a master analytic scheme, which will make possible the detection of previously unanalyzable organic compounds and which will eventually result in even broader exposure assessment studies.

Two types of organic compounds still elude identification and measurement by standard gas chromatography-mass spectrometry tests: non-volatile compounds, because they will not pass through the gas chromatograph; and compounds whose mass spectral "fingerprints" are not currently on file. However, techniques to identify and measure these compounds are presently being developed.

A quality assurance program for drinking water has been developed on the national level to provide the support necessary to maintain safe drinking water systems. The objective of this program is to develop and maintain a national quality assurance program to improve and document the precision, accuracy, and intercomparability of all drinking water measurements. It is also designed to provide a centralized quality assurance overview of all Agency programs and laboratories gathering and using drinking water monitoring data. Major activities include standardizing and validating total measurement systems; developing and distributing quality control samples and reference materials; performing on-site inspections of laboratories; evaluating the performance of measurement systems and operators; developing procedures and acceptance criteria for laboratory certification; and evaluating and approving alternate test procedures for both national and limited use. The Agency uses the procedures, protocols, and materials generated by this program to assure that the data produced by the measurement systems are accurate, intercomparable, and legally defensible.

Health effects. The potential carcinogenic effects of organic contaminants in drinking water is a major focus of the program's research, with some attention being given to mutagenic and teratogenic effects as well. The primary effort involves the suitable preparation of organic concentrates for testing and the subsequent identification of biologically active fractions. Key compounds will receive long-term toxicologic study.

To develop guidelines limiting the amounts of chemicals in drinking water that are thought to be cancer-causing agents, human health data is currently being collected from a variety of epidemiological studies that are focusing on communities where the occurrence of cancer exceeds expected rates. The relative contribution made by drinking water to the total exposure to these carcinogens will be determined through chemical analysis. Health risks can be derived from these findings, and guidelines can be established.

To identify any measurable increased risk of disease from specific organic substances, EPA will study those populations whose drinking water is known to be contaminated by a certain few synthetic organic compounds. Results, it is expected, should provide valuable data on the human health effects of long-term exposure to environmental contaminants. Also to be studied will be the risks posed by non-trihalomethane organics. Information will be obtained by comparing the incidence of disease in various populations with drinking water supplies similar in trihalomethane concentrations but dissimilar in non-trihalomethane organics.

Serious consideration also will be given to the development and modification of bioassay methods capable of characterizing and monitoring the hazards found in drinking water supplies. Because current *in vitro* assay systems such as the Ames test may not be sensitive enough for use with unconcentrated waters and may not accurately define the risks posed to human health, the need for improved assay procedures is significant.Once such methods are developed, proven reliable, standardized, and applied, they may be used in place of the detailed chemical analyses that are currently required after MCLs are established for individual compounds. Throughout the research effort involving bioassay methods, close coordination with similar work taking place elsewhere in EPA will be maintained.

Recently refined short-term *in vivo* assays are presently being used to test water from 15 American cities and from pilot plants studying alternate treatment techniques. Test results will be extrapolated to determine the risks posed by any of the carcinogenic and mutagenic substances in the treated water. Successful adaptation will have definite advantages over the current long-term animal feeding studies.

Treatment. Various surveys have shown that certain organic compounds retain their form through rivers, reservoirs, treatment, and distribution systems, and that other organic compounds, created or added during water treatment, are equally persistent. However, data from pilot plant activities and modular- and full-scale field evaluations have demonstrated that a considerable reduction in certain chlorinated organic by-products can be attained by modifying disinfection/chlorination and other treatment practices. Currently under study are the organic halogen (OX) compounds that occur widely where chlorination is practiced. Research will continue to investigate the influence of such environmental factors as precursor concentration, disinfectant dose, temperature, pH, and time on the rate and quantity of OX material formed.

More economical and efficient treatment methods are being explored through large-scale pilot plant and full-scale plant projects to determine the fate of various organics, not only during water treatment but throughout the entire system—from source to tap. These field-scale projects are being conducted in cooperation with drinking water utilities and local and state governments to determine how effectively and at what cost certain experimental treatment processes remove specific environmental contaminants. Such unit processes as coagulation, granular activated carbon beds, powdered activated carbon, polymeric resins, ozonation, aeration, ozonation/ultraviolet radiation, oxidation plus adsorption, and chlorine dioxide will be evaluated.

The field-scale research projects demonstrate how existing technologies will perform under actual operating conditions. The results of the studies will facilitate the prudent prescription of water treatment in cases where a health risk from organics is suggested and monitoring is not practical.

Inorganic Contaminants

The objectives of the inorganic contaminants research program are to locate and measure inorganic pollutants, determine whether they pose a health threat, and evaluate means to control their occurrence in drinking water. A number of such inorganic pollutants—nitrates, metals, radionuclides, and asbestos, for example—have already been found in tap waters in various parts of the country. During the study, improved methods for analyzing such inorganics will continue to be sought. The program also will develop analytical methods to determine the species of an inorganic contaminant as well as its concentration; improve current multi-element analysis capabilities; and work to develop real-time inorganic monitoring devices. Alternate test procedures to measure MCL contaminants will continue to be evaluated and, where appropriate, will be approved as monitoring procedures. Water samples for quality assurance and performance evaluation will continue to be provided to water supply laboratories, particularly those attempting to meet the certification requirements of the SDWA. Also, critical water stabilization factors will be identified and cost-effective treatment methods to prevent corrosion of metal or asbestos-cement pipes will be developed.

Health effects. While past epidemiological studies have indicated a potential link between cardiovascular disease and certain inorganics in drinking water, most of the studies suggesting this link have been rather broad in nature, concentrating more on geographical areas than on the health histories of specific individuals. Thus, other known cardiovascular risk factors such as smoking, family history, exercise, and diet were not considered along with water quality data. Under the inorganic contaminants research program, a more refined study of the link between cardiovascular disease and drinking water will be initiated. Test subjects will be a group of middle-aged men. Tap water routinely used by the participants will be characterized for some 80 elements, and physical exams, interviews, and laboratory tests will be conducted to establish other cardiovascular disease risk factors. The results of this study will enable identification of any critical elements in the water and will allow for a precise quantification of the degree of risk such elements present in conjunction with other known non-water risk factors. If drinking water elements are causally implicated in the research, it is estimated by the National Research Council that optional conditioning of drinking water could reduce the annual cardiovascular disease mortality rate by as much as 15% in the United States, thereby saving an estimated 150,000 lives per year.

Other epidemiological studies are being conducted to establish the relationship between cardiovascular disease—particularly hypertension—and sodium and 35 other inorganic contaminants that may occur in drinking water. Long-term toxicologic studies have been initiated to determine if various combinations of barium, calcium, magnesium, lead, cadmium, and sodium in water have an impact on the development of cardiovascular disease.

Additional projects will include ongoing toxicologic studies on lead to determine whether development of the central nervous system may be hampered by what are currently considered normal human blood lead levels. Also, the bioavailability of certain metals—including lead—in hard and soft waters and in food are being studied, and safe levels will be determined.

An inorganic contaminant of particular concern is asbestos, since it is a possible carcinogen and co-carcinogen when ingested. Studies will determine whether asbestos from mining operations, asbestos-cement water pipes, and natural erosion contribute to increased cancer rates. Short-term animal experiments will examine the effects of various asbestos fiber lengths and explore the causal mechanisms that may determine the potential of asbestos to be a co-carcinogen. To ensure accurate asbestos fiber counts, improvements will be made in the collection, shipping, storage, and preparation of water samples.

Treatment. Treating water to remove inorganics can present a technological problem, particularly for small communities. EPA's continuing effort to improve treatment technologies will include investigations of those polymers that may be used to improve coagulation or filtration, as well as those chemicals that soften water to reduce radium, iron, manganese, and calcium concentrations. Ongoing bench and pilot-scale studies will examine a number of treatment processes for their effectiveness in removing arsenic, barium, cadmium, chromium, fluoride, lead, mercury, nitrate-nitrogen, and selenium and radionuclides. The processes being studied include:

- conventional water treatment processes of alum and iron coagulation;
- lime and excess lime softening;
- powdered and granular activated carbon;
- ion exchange;
- activated alumina treatment; and
- reverse osmosis.

Inorganic contaminant treatment research will focus on applying technology to small communities. Several studies will develop design, operating, and cost data for technologies capable of removing one or more contaminants from a variety of source waters. Field testing and cost analysis of full-scale facilities will be a necessary aspect of this future work.

Existing package plant systems currently used by small communities also will be examined to determine their effectiveness in removing particulate material from a variety of surface waters. A technical evaluation of the package plants will be provided to promote a more widespread application of effective systems by small utilities. Methods to minimize costs of successfully demonstrated treatment technologies will be emphasized. Limited evaluations of home treatment devices are being completed. To help solve some small system water quality problems, the relative value of regionalizing several water utilities is being examined, along with the parameters for determining the common sense of this approach.

Protocols for evaluating drinking water treatment additives will also be developed.

Microbial Contaminants

Treatment. Chlorination has been the primary method used in this country to destroy microbes in drinking water. While this disinfection process has proved to be highly successful in reducing waterborne disease, microbiological contaminants in drinking water are still a concern, particularly in light of recent increased use of alternative disinfectants and of possible changes in treatment processes. The microbiological contaminant concern has been deepened by the discovery of disinfectant-resistant pathogens and by the fact that only limited treatment is applied to purify water in many parts of the country.

Currently, pilot and field-scale studies are being conducted to determine whether changes in treatment processes will bring about new microbiological problems. These studies will examine such changes as shifts in the location of disinfectant application, the use of alternative disinfectants, conversion of rapid sand filters to granular activated carbon filters, the use of biologically activated carbon as a treatment unit process, and any other methods that may reduce undesirable treatment by-products. Field studies are planned to evaluate how water turbidity affects the efficiency of microbiologic disinfectants. Also to be studied are the physical, chemical, and microbial characteristics that permit microbes to grow in water distribution systems with inadequate treatment practices, such as poor pipe corrosion control.

Health effects. In cooperation with the Center for Disease Control, outbreaks of waterborne infectious diseases will be investigated to identify the etiological agents in water, determine their route of entry, and recommend corrective action to prevent recurrence. Particular attention will be paid to the role played by exotic or newly identified bacterial agents such as *Legionella*, which is mainly a multisystem illness primarily involving the pulmonary system, and to new agents of gastroenteritis, e.g., *Aeromonas*, *Campylobacter*, and *Yersinia*. Also to be studied will be viral and parasitic agents. Study of the parasite *Giardia* to determine how it is transmitted to humans will continue. Control methods to break the disease cycle will be recommended as a result of the data obtained from these studies and from investigations of the efficiency of various treatment processes for deactivation or removal of the agents. Current studies will be expanded to investigate the health significance of *Giardia* in surface waters that have received minimal or no treatment, and of *Giardia* cysts that occur in wild animals inhabiting watersheds. Epidemiological studies to determine the incidence of giardiasis in humans who consume contaminated waters also will be initiated.

Monitoring. Water quality monitoring is an ongoing process. However, the traditional concept of determining water quality by measuring indicator organisms rather than specific pathogens is frequently challenged. For example, some specific pathogen occurrences, such as *Giardia*, do not readily correlate with the standard coliform test; *Giardia* occurrences have been found in waters disinfected to remove coliforms—the indicator of sanitary significance and disinfection effectiveness. Therefore, the efficacy of the standard coliform test will be evaluated, and the possibility of using other indicators will be investigated. Microbiological sampling, holding-time, and preservation procedures will continue to be improved, as will analytical methods for both indicator organisms and pathogens, including viruses and protozoans.

Groundwater Contamination

Developing baseline data. For many areas of the country, only limited groundwater data are available for use in ranking potential contamination sources, evaluating their relative adverse impacts on human health, and, in many instances, defining feasible pollution prevention and control techniques. The research program is designed to provide additional information on the characteristics of groundwater contamination.

The success of this data-gathering effort depends on the accurate measuring of contaminants in groundwater. Thus, soil permeability tests, particularly for industrial wastes containing significant amounts of organic solvents, will be developed and standardized. An emphasis will be placed on determining the gross biological activity in saturated and unsaturated soils; once determined, this information could lead to data on the magnitude of industrial waste contaminants in groundwater. Methods will be promulgated for the effective use of tracers, such as radioisotopes, to investigate groundwater.

To maintain groundwater quality, knowledge of the vulnerability of nearby aquifers is crucial. In order to help select future sites for underground waste storage and disposal facilities, methods of characterizing the earth's sub-surface will receive special emphasis. Complex resistivity techniques for locating contaminated areas in the sub-surface environment will be evaluated. Natural microbiological populations in groundwater under varying hydrogeological situations will also be studied, and the presence of aerobic and anaerobic species and cyclic population densities will be examined. Finally, trace element analyses will be conducted to correlate the background quality of the aquifer with aquifer type and age.

Contaminant transport. Contaminant transport research projects are, in the main, designed to determine which parameters are important in contaminant transport and how those parameters vary within soil and aquifer systems.Such knowledge is vital to determine the degree of protection necessary to maintain groundwater quality. Since a great deal of information on the movement of contaminating metals and inorganic chemicals in the saturated and unsaturated zones of the earth's subsurface has already been generated by the U.S. Geologic Survey, and since organic chemicals have been implicated in a number of groundwater contamination incidents and microbiological contaminants have been discovered in many rural wells, EPA program studies will focus on the transport and transformation of specific organics and viruses. We will examine the movement of priority organic pollutants through a column of soil to evaluate their probable impacts on groundwater should such compounds be released into the soil. The results of this research will be particularly important in predicting the consequences of chlorinating wastewater prior to land application and of using such products as septic tank cleaners.

Also to be examined will be the transport and fate of a selected group of organic compounds in simulated high-rate land application wastewater treatment systems. Models to describe the behavior of these compounds will be developed, tested, and refined. The development and field evaluation of monitoring will be considered under this research as well, since groundwater monitoring is essential for the quick detection of any problems with the land treatment of wastewater.

The persistence of many consent decree compounds in aquifers is another area that will be studied. Included in this study will be phenols, phthalates, volatile chlorinated hydrocarbons, chlorinated benzenes, and aromatic ethers.

Informed decision making. Resolution of conflicts about potential aquifer use requires information on the impacts of specific sources of groundwater contamination, as well as the economic benefits gained from not polluting weighed against the costs of groundwater degradation. To provide that information, the research will describe the transport and fate of pollutants, characterize subsurface environments, and then concentrate on specific pollution sources. This work will supplement studies on the background quality of groundwater in 34 states, studies that have so far identified 19 discrete sources of groundwater contamination ranging from septic tanks and cesspools to deposition from the atmosphere. The new research will provide information about several other contamination sources, among them improper water well construction. The costs necessary to eliminate contamination or rehabilitate wells will also be evaluated. Since aquifer reclamation and other groundwater protection projects cannot be evaluated for effectiveness due to a lack of knowledge about trace organics in the water, EPA will develop a non-contaminating submersible pump and drilling and construction materials, thus permitting more accurate evaluation.

Other groundwater projects. There are several other research projects planned. These include:

- development of methods to calculate the radius of areas influenced by injection wells;
- development of models to describe phenomena associated with groundwater recharge, i.e., where waste from advanced treatment facilities is injected into groundwater to reduce the intrusion of saltwater, or to provide water for eventual reuse;
- studies to promote groundwater protection through better construction, operation, and maintenance of septic tanks;
- studies to promote cooperation with EPA's wastewater program;
- studies into the extent and type of organics and viruses moving into soils and groundwater from high-rate land application systems; and
- development of quick and inexpensive monitoring methods for locating abandoned wells that could influence the movement of waste fluids from injection wells.

Reclamation: A conservation alternative. Reclaiming polluted groundwater is a relatively expensive, long-term process, one traditionally not undertaken because less-expensive water sources have been available. However, since incidents of aquifer pollution—such as that at Love Canal—are proliferating, and since the number of water-short areas in the nation is increasing, the reclamation of groundwater is becoming an attractive conservation alternative. EPA plans to develop a groundwater reclamation research program that will use, as its partial base, results from the program's transport and transformation studies and its groundwater methods development research.

EMERGING PROBLEMS AND RESEARCH NEEDS

After reviewing available literature and field experiences, the Drinking Water Research Committee determined which major water problems need further research. These problems were then placed in priority order, and ORD is currently attempting to develop appropriate solutions in a timely manner. However, as research into these problems is conducted, unexpected results often change the research objectives. These changes are sometimes the result of increased sensitivity in contaminant measurements; in other instances, a new bioassay method may indicate for the first time that a contaminant is a carcinogen or mutagen. Two recent examples of such discoveries are the hazards posed by asbestos and chloroform. Test findings resulted in a sudden and marked shift of research interest and resources in the 1970s.

Other less-well-defined problems may produce adverse effects as new regulations take effect, and such possibilities must be investigated. For example, the new trihalomethane MCL of 0.10 mg/L may motivate some water utilities to use disinfectants other than chlorine, such as hydrogen peroxide, iodine or bromine chloride. Before any substitutions are made, however, it should be determined if these compounds create relatively risk-free by-products.

Other research problems are created by the annually increasing number of materials used in treating water and protecting the internal surface of pipes and tanks from corrosion. Thus EPA must find systematic ways for evaluating the impact of these materials on water quality. Some of the short-term bioassay methods being developed for other trace contaminants may help screen these materials. An effort should also be made to develop a protocol for measuring the benefit of, as well as the risk from, these materials, in order to help establish their relative value. While such a protocol is being developed, it may be found that some of the materials are not worth the expense entailed in the toxicologic testing.

Potential problems are also definitely posed by genetic engineering designed to degrade refractory-type organics. The human health significance of such genetically altered microorganisms must be determined; also to be determined is whether chlorine-resistant organisms can develop during treatment and, if necessary, appropriate control measures found. To this end, a bacterial indicator better than coliform may have to be sought.

Another problem that needs to be explored is the contribution made by water contaminants to the human body relative to the body intake from all other sources including food, air, etc. This study is particularly necessary for volatile organics; also, inorganic compounds that shift valence state easily need to be studied in all phases of their passage through the human body.

Treatment plant design. A continued analytic effort to better understand the chemistry involved in identifying and quantifying the non-volatile organics in water will ultimately help engineers design better treatment plants. Establishing a relationship between specific chemical concentrations or between a surrogate and its potential toxicity will also help the treatment plant designer and operator by more precisely demonstrating the benefits of more rigorous treatment. Additionally, if raw water quality could be monitored to detect currently unknown adverse changes in contaminants, then treatment plant design and operation could be planned for typical extremes.

Practical reclamation techniques. Practical reclamation techniques that are capable of decontaminating the soil area of groundwaters serving small water systems should be developed. If they are not, economically feasible processes will have to be invented that will reduce volatile organics or inorganics such as nitrate, fluoride, arsenic, or radium in withdrawn water without creating unmanageable waste products.

FUTURE TRENDS

With the probable continued shift of populations to the South, water shortages can be expected to occur there more frequently. Increased nationwide demands for water will necessitate supplementing sources with recycled, highly treated wastewater or mineralized groundwater previously thought to be unusable. Under these circumstances, sodium may become an expensive treatment problem as will the disposal of residues from various treatment processes.

In a given region, the per capita surveillance and management costs for small utilities using poor water sources may become excessive, suggesting that new ways of collectively managing these small systems may need to be developed.

In communities with as few as 25 to 50 persons, a central treatment plant may be unfeasible. Alternative solutions may include using service contractors to manage point-of-use treatment devices or distributing safe bottled water to each household for drinking and cooking. Methods for making comparative cost analyses will have to be developed to help managers and consultants sort out these options.

Also, as more synthetic organics are manufactured and used throughout the country, treatment barriers (i.e., obstacles to the passage of contaminants created by treatment processes) should be developed to protect consumers whose water sources receive industrial wastes.

DRINKING WATER RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Organic Contaminants Including Disinfection By-Products	Conduct health effects studies to assess carcinogenicity, mutagenicity, teratogenicity, and toxicity of commonly found organics		△	△ △		▲
	Evaluate health effects of disinfection by-products		△			
	Conduct field-scale research projects for the removal of organic contaminants	△ △	△	△	△	▲
	Evaluate specific treatment technologies to support MCL's for specific compounds	△	△	▲		
	Evaluate and develop methods for control of by-products from the use of disinfectants in treatment systems	△	△		▲	
	Develop recommendations for protocols on coagulate aids				▲	
	Conduct preliminary evaluation of carcinogenic activity associated with coal tar and asphaltic base paints and coatings			△		
Inorganic Contaminants (Including Asbestos)	Conduct long-term toxicologic studies to determine relationship of barium, calcium, magnesium, lead, cadmium, and sodium in water to cardiovascular disease	△		△		
	Determine health effects of asbestos, nitrates, and fluorides in drinking water	△	△	△		
	Apply inorganic treatment technology to small communities, with emphasis on nitrate, barium, and fluoride removal	△△	△	△		
	Publish manuals for removal of many specific contaminants	△	△			
	Conduct pilot and field studies on corrosion control methods, prepare manual	△	▲			

▲Final report, manual or user's guide; △Interim report or manual; ●Prototype equipment and report;
★Interim or final criteria formulations; ○Final protocol; ■Continuing effort; □Other, self-explanatory

DRINKING WATER RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Microbiological Contaminants	Prepare annual review of waterborne disease outbreaks	□	□	□	□	□
	Evaluate health risks from exotoxins, endotoxins, and pathogens		△ △	△		
	Determine adequacy of coliform media and procedures, and investigate alternatives		△		△	
	Determine efficiency of unit processes other than disinfection as they are applied to control of viruses, protozoans, and bacteria	△	△			
	Determine occurrence and ecological effects of microbiological contamination and growth in distribution systems	△				
Groundwater	Evaluate methods for determining subsurface contamination from the surface and methods for groundwater studies		△ △	△		
	Examine the transport and transformation of organic compounds and biological contaminants in the subsurface environment	△△ △	△		△	
	Provide information and guidance to the user community in the form of manuals, films, videotapes, etc.	△△	△			

WATER QUALITY

Four of ORD's thirteen research committees pertain to water pollution control. Research plans for ambient water quality management are covered in this chapter; chapters 13 and 14 deal with research to control water pollution from municipal and industrial sources, and chapter 11 covers research on drinking water supplies and ground water management.

The Objective of Water Quality Research

The fundamental objective of EPA's water quality research is to provide assessment methods and information that will help federal, state and local governments make water pollution control decisions that are scientifically defensible, cost-effective, energy efficient, minimally disruptive to ecosystems and that make optimal use of water resources. The research plan to achieve this fundamental objective will, for the next five years, concentrate on support of:

- future water quality criteria and standards;
- water quality-based effluent limitations;
- water quality management strategies involving point and nonpoint source control tradeoffs;
- ocean discharges and dumping;
- hydrologic modifications in wetlands and other aquatic systems; and
- national strategies for water quality protection and for assessing progress of water pollution control efforts.

These six research areas reflect the fact that the current means to achieve water quality goals are through regulations formulated to meet water mandates set forth by Congress. Furthermore the research is in response to information requested by federal, state, and local water resource managers to meet the congressional needs.

In structuring the plan to fulfill these research responsibilities, EPA believes that tomorrow's water manager will require a far more comprehensive insight into water problems than does today's manager. In the future, for example, individual water systems will be viewed as parts of total ecosystems and will be managed to deal with simultaneous stresses from point sources, nonpoint sources, intermedia exchanges, and natural events. Up-to-date information on the state of the water ecosystem will be required in order to predict the consequences of the multiple stresses. Additionally, understanding the relationships between water quantity and quality and between surface and ground water quality will be a part of the water manager's responsibility. Much of the information, analytical methods, and monitoring systems technology to meet these and other future management duties is nonexistent and thus is being developed as part of our research efforts. In short, EPA believes that to ensure future water quality, the right planning must be done now.

THE RESEARCH PLAN

EPA is pursuing the goals of the Clean Water Act (CWA) in two phases. Phase I emphasis is on establishing minimum or base level point source pollution control throughout the country. The level of control is determined by state-of-the-art technology and cost, regardless of site-by-site receiving water effects. Regulations for these technology-based controls will be largely promulgated by FY 1981 and incorporated into revised effluent discharge permits shortly thereafter. Pollution control facilities constructed in accordance with the new requirements should be completed by July 1, 1984.

Phase II emphasizes development and implementation of a national water quality strategy for the cases in which base levels of controls are insufficient. The nation's energy and economic problems will be specifically considered in the strategy as will site-specific water quality objectives.

Our water quality research plan parallels this two-phased approach to improve and protect America's waters. The first research phase, extending from the present through FY 1982, will deal with major, high-priority current problems. The second phase, beginning in FY 1982 or shortly thereafter, will support development of national water quality strategies by providing data about the emerging problems most likely to affect those strategies.

The Current Problems

The most immediate problems are of a technical assistance nature. In response to the Natural Resource Defense Council vs. Train suit, for example, EPA must issue water quality criteria, effluent guidelines, and associated standard reference measurement methods covering 65 toxic pollutants or pollutant classes (expanded to 129 chemicals). The previous effort to assist the Office of Water and Waste Management to comply with the court's decision in this case included a compilation of existing health and ecological data which was then used to prepare water quality criteria for those chemicals which met minimum data base requirements. Work is now under way to fill data gaps as necessary so that criteria for all the chemicals can be established. A substantial effort has also been undertaken to identify reference measurement methods available for the 129 chemicals, evaluate each method's precision and accuracy, and select the best methods.

A second immediate problem involves a need to revise ocean disposal regulations developed under the Marine Protection, Research, and Sanctuaries Act for waste residuals and dredged materials. The revisions are necessary to ensure that requirements for evaluating and handling these materials are consistent with the latest state-of-knowledge. Our effort to support this requirement consists of providing technical assistance in the revision of the regulations in question.

A number of other regulations also are undergoing routine development or revision. Some key regulations expected to receive emphasis over the next year or two by the Offices of Water Regulations and Standards and Water Enforcement include those covering water quality standards, the list of toxic pollutants, designation and determination of hazardous substances, point source wasteload dredged or fill material. Our major research efforts to meet some of the expected information needs of these activities include improvement of the procedures for deriving water quality criteria, making wasteload allocations among dischargers, and more cost-effectively and accurately assessing the impacts of proposed pollutant discharge and disposal actions and of proposed remedial measures.

Other research is supporting the development of more cost-effective approaches to screening and quantifying toxic chemicals in ambient waters, so that monitoring systems technology will be available to satisfy the 1985 requirements. Current technology is cumbersome and expensive, and allows the routine monitoring of only a few known toxicants. This research should result in a basinwide, or even nationwide, network capability which will detect unknown or new chemicals, as well as known toxicants.

Current priority problems of a longer-term nature are associated with toxic pollutant management, nonpoint source control, dredge and fill operations, and protection of groundwater quality. The relative priorities of these problem areas under the aegis of the Water Quality Research Committee are generally in the order in which they are listed. However, groundwater-related problems, which are addressed primarily by the Drinking Water Research Committee and are discussed in Chapter 11, are a very high priority of the Office of Research and Development.

Toxic pollutant management. The control of toxic pollutants in water and other media will be a major EPA thrust for at least the next decade. To effectively control the toxic pollutants, current and future water-related problems need to be identified, risk and benefit tradeoffs identified and evaluated, and the most cost-effective control strategy developed and implemented. Precision in determining appropriate control levels will be crucial because the costs of additional increments of control are generally very expensive, but the impacts on human health and aquatic life of inadequate control of carcinogens, teratogens and other toxicants could be tragic. Essential to effective toxicant control are analytical tools and data bases that efficiently identify or predict: direct and indirect sources, primary environmental pathways of movement and accumulation, persistence, resultant human and environmental exposure levels, risks associated with a range of exposure levels, and reductions in exposure levels that would result from various reductions to rates of environmental release. In addition, to effectively implement pollution control strategies (primarily through the National Pollutant Discharge Elimination System of effluent permits), a capability is needed to:

- rank pollution sources according to their relative environmental impacts;
- determine necessary permit conditions;
- ensure continuous compliance with permits; and
- ensure and document the accuracy of water quality data indicating permit violations.

At present, however, deficiencies in the technical data base include: a lack of water quality criteria for all priority pollutants; marginal health and ecological effects data to support proposed criteria for several priority pollutants; insufficient information to translate laboratory-derived criteria to actual site-specific field situations; a lack of low-cost, practical methods to identify and rank the seriousness of water quality problems; a lack of quantitative, standardized measurement methods; a lack of suitable quality assurance procedures; and inadequate methods and data to predict levels of exposure to the amounts of toxic pollutants that will be released as a consequence of various control strategies.

Nonpoint source control. Attention to date has been given primarily to the control of point sources of pollution, thus additional increments of point source control will be more expensive to achieve. Accordingly, greater consideration must now be given to nonpoint source (NPS) control, which, in conjunction with point source control, will more cost-effectively achieve the water quality goals of the CWA. Grant funds authorized under Section 208 of the CWA are therefore being directed to the identification, characterization, and demonstration of NPS management practices potentially applicable on a national scale. Demonstration of the effectiveness of selected NPS management practices at given locations, alone, will not be sufficient, however, to ensure their wide-scale use under the non-regulatory 208 approach. Success also will require a capability to accurately predict the benefits that would accrue from the implementation of NPS controls at specific sites. Such a capability does not exist. The needed methodology must be able to identify both the improvement in ambient water quality that would result, and the actual water use and economic benefits of that incremental improvement (e.g., support of a more desirable species of sport fish).

Dredge and fill operations. EPA's responsibilities under the CWA include developing and administering guidelines for the review of applications for dredge and fill permits issued by the Army Corps of Engineers. EPA also is responsible for overseeing transferral of the permitting authority to qualified states. The guidelines should include recommendations of data collection and procedures for predicting impacts on aquatic ecosystems from discharges of dredged or fill materials at proposed or existing disposal sites. The guidelines should also provide a framework in which judgments can be made on the environmental significance of the impacts.

At present the procedures and data essential to fulfill the guideline development responsibility are incomplete. Needed are field assessment techniques, background information about typical ecosystems and impacts on them from dredged and fill materials, and techniques for predicting site-specific impacts of proposed discharges. In addition, we must be assured that methodologies for chemicals in freshwater are suitable for marine application and, if unsuited, they are corrected or adapted.

Research Planned for Current Long-Term Problems

Toxic pollutant management. In response to the need for an improved technical base applicable to the systematic management of toxic pollutants, work is under way to provide:

- analyses of health and ecological risks from exposure to specific high priority pollutants;
- quicker and more cost-effective test procedures for evaluating a broader range of health and ecological effects of specific new pollutants, as necessary to produce more rational and accurate water quality criteria;
- preliminary procedures for translating laboratory-derived water quality criteria for consent decree pollutants to site-specific field conditions;
- a preliminary guide for ranking point sources of toxic pollutants according to their relative environmental impacts;
- more cost-effective techniques for identifying and quantifying toxic pollutants in surface waters, sediments, and biota and associated quality assurance procedures; and
- predictive methods for determining environmental exposure levels that would result from alternative toxic pollutant management strategies.

Nonpoint source control. Research is also under way to provide a portion of the technical base required to effectively address NPS pollution problems. Gross assessment techniques for predicting NPS loadings of the common (i.e., non-toxic) pollutants and their impacts on receiving water quality and for evaluating point source versus NPS tradeoffs have been developed and are being field tested. They also are being expanded to address impacts of toxic pollutants, including those that move between the sediments and water column. Work also is under way to characterize the ecological effects of NPS pollution and to provide methods for assessing the human health and ecological risks associated with various levels of NPS pollution. Work directed at development of the data base required to predict reductions in rural NPS loadings that would result from the application of various existing control practices has been discontinued at the direction of the Office of Management and Budget (OMB). This work would have provided the remaining link necessary to identify water quality and economic benefits associated with the implementation of any given rural NPS management practice. With the above exception, methodologies are being developed for assessing ecological effects of NPS runoff and evaluating the costs and benefits of alternative levels of rural NPS control and tradeoffs between point source and NPS controls.

Dredge and fill operations. Significant research efforts will supplement the extensive technical assistance now provided to the Agency's dredge and fill program. Research is under way to develop procedures for cost-effectively valuating dredged materials and proposed disposal sites. With the procedures, EPA will be able to estimate the environmental impacts of dredge spoil to be discharged by permit applicants. Efforts are also under way to characterize the structure and function of natural and modified aquatic ecosystems (including wetlands) as a basis for predicting the consequences of dredge and fill and other human activities on these systems.

Emerging Problems

The primary emerging water quality management problems already have been alluded to in the discussion of current long-term problems. As Phase II of the Clean Water Act implementation plan is pursued over the next decade and beyond, there will be an increasing awareness of and sensitivity to the nation's protracted energy and economic problems. Attention will be given first to translating the goals of the Act into water quality objectives that are realistic, feasible, site-specific, and quantitative; the focus will then shift to identifying the water quality management strategy that is most cost-effective and energy-efficient for achieving the goals.

For example, the greater costs associated with higher levels of point source control (e.g., advanced waste treatment for municipal wastes), will make technically sound planning increasingly critical to provide cost-effective solutions. The planning must consider application of realistic water quality criteria for each designated water use within each watershed; designation of water uses that are feasible to attain and maintain over the next several decades; and employment of various combinations of point and nonpoint source controls tailored to each watershed in the management of the full range of pollutants of concern. Cost-effective solutions to achieve optimal controls may entail the use of water course or watershed modification or non-source control techniques (e.g., in-place toxicant removal, flow augmentation, creation of artificial wetlands adjacent to streams to intercept and treat runoff, etc.), in addition to source control techniques. This dual approach has been and will continue to be employed to a great extent in the clean lakes program. The relationship between quality and quantity and the role of conservation will also be recognized in future water quality management planning.

Pollutants and their impacts that will receive the single greatest emphasis over the next several years will be toxic and hazardous chemicals. Other constituents to receive significant attention will be sediment, nutrients, and salinity. The importance of toxic and hazardous chemicals in a highly industrialized society will be recognized in their control. Thus, in future environmental decisions primary consideration will be directed at specifying and regulating use and disposal practices that will maintain at acceptable levels environmental risks posed by these chemicals, as opposed to simply approving or banning their use or disposal. Risks posed by existing environmental levels of toxic and hazardous chemicals also will be evaluated and taken into account in such risk assessments. This approach will require more sophisticated assessments of actual and potential environmental exposures and associated risks than were required in managing conventional pollutants. Greater consideration also will have to be given to the multimedia aspects of toxic and hazardous chemicals, from the standpoints of both environmental exposure assessments and disposal practices. This will require an integration of management programs for water quality, drinking water, and solid waste to provide the most cost-effective environmental protection.

Pollutant sources other than publicly owned treatment works and industrial point sources to be given serious attention in the 1980s include abandoned hazardous waste sites, urban storm runoff and runoff from farming, logging, mining, and construction activities. Increased attention also will be given to the protection of wetlands from dredge and fill operations and other human activities, and protection of groundwaters from contamination by landfills, saltwater intrusion, underground injection, storage of hazardous waste, and other sources of pollutants. In addition, greater attention is expected to be given to the problems created by the disposal of pollutants in marine waters.

The research needs are shaped primarily by the planned broadening of program emphasis, going beyond the technology-based point source control approach to include a water quality-based approach. This will substantially increase emphasis on the control of pollution caused by activities other than point source discharges and will require the demonstration of cause and effect relationships. The needs are also strongly influenced by the high priority being given to the control of toxic chemicals, the increased concern over groundwater quality problems, and added concerns over national economic and energy problems.

In essence, the Agency (in concert with state and local programs) will be striving to provide a water quality management program capable of more efficiently, effectively, and systematically identifying: (1) existing and potential future water quality problems and their origins; (2) attainable (i.e., favorable benefit/cost considerations) site-specific water quality goals relevant to all of the pollutants of consequence; (3) the current and future levels of pollutant control necessary to achieve the goals and the most equitable allocation of allowable loadings; (4) the most cost- and energy-effective control strategy for achieving assigned loadings; and (5) the most appropriate institutional mechanisms for implementing the control strategy. Such a capability will require the availability and use of the following technical base:

- a range of cost-effective monitoring and measurement methods for identifying and quantifying pollution problems and evaluating compliance with source control and ambient quality requirements;

- field-validated surface and groundwater quality criteria known to closely reflect conditions actually required for various water uses, including the protection and propagation of fish, shellfish, and wildlife and for recreation in and on surface waters, and that are applicable to identification of impacts of NPS pollution and deposits of sediment-bound pollutants on aquatic life, recreation, and other uses; the criteria also should be structured to permit identification of incremental benefits that would result from additional increments of pollution reduction;
- methods (involving the use of predictive models) for translating water quality goals into point and nonpoint source loading allocations in water quality limited segments (and that take into account deposits of sediment-bound pollutants);
- methods and associated data bases for evaluating environmental, economic, and energy costs and associated benefits of alternative water resource management strategies, including various combinations of point and nonpoint source controls and water body restoration and modification measures; the methods also should be applicable in evaluating the costs and benefits of dredging and alternative schemes to dispose of dredge spoil and other waste residuals;
- nonpoint (and point) source control techniques, non-source control techniques such as flow augmentation, and water body restoration techniques that are highly cost- and energy-effective and whose costs and effectiveness are known for the range of operating conditions that would be encountered in their potential use;
- alternative strategies for the effective implementation of water quality management/control systems, alone and in conjunction with related public or private activities (e.g., flood control or soil conservation) and that take into consideration the various legal, institutional, social, economic, and energy constraints.

The existing technical base in the above areas is deficient in many respects. It was developed primarily to provide water quality managers with the tools needed for controlling point sources of common (i.e., nontoxic) pollutants, which until recently were the focus of federal, state, and local pollution control efforts. This technical base must be upgraded if we are to recommend cost-effective solutions to problems resulting from: nonpoint sources of both nontoxic and toxic pollutants; point sources of toxic pollutants; in-place toxic and other pollutants (viz., accumulations in bottom deposits of water bodies); disposal of dredged materials; restoration and subsequent protection of deteriorated lakes; ocean disposal of waste materials; other human activities adversely affecting aquatic ecosystems (including wetlands); and intermedia transfer of toxic and other pollutants.

Much of the research under way that is directed at resolving the current long-term problems described above is also relevant to the emerging problems. Once outputs currently being pursued are achieved, some shifts in emphasis will be necessary. Most of these adjustments will have to be made in FY 1982 or shortly thereafter in order to provide the technical base needed in the mid-1980s and beyond in a reasonably timely fashion.

Research in FY 1982 will be directed at:

- development and selection of measurement and monitoring methods and systems, including gross screening techniques, and associated quality assurance requirements for the cost-effective identification and quantification of ambient pollutants or pollutant classes warranting concern; emphasis will be given to toxic pollutants;
- determination of the effects of priority pollutants on human health and aquatic ecosystems as needed in identifying minimum water quality requirements and development of procedures for translating water quality criteria derived under one set of laboratory conditions to any of a variety of field conditions encountered in the environment; the latter will become increasingly important as attempts are made to more precisely define water quality requirements area by area in order to maximize the cost-effectiveness of pollution control expenditures;
- development of methods (involving the use of models) for predicting the movement, persistence, and fate of priority toxic pollutants in surface waters and sediments, as necessary in determining exposures resulting from the proposed uses and rates of releases of these substances and in identifying maximum acceptable site-specific rates of release;
- documentation of the effects of nonpoint source pollution and development of a methodology and associated data base for determining site-specific water quality benefits that would result from the implementation of various levels of nonpoint source control;
- development of techniques for assessing the

impacts of ocean discharges and dumping activities on the marine environment;

- development of techniques for assessing the impacts of dredge and fill operations on fresh and marine ecosystems;
- conduct of studies of potential impacts on human populations and aquatic life that would result from projected (or actual) exposures to selected toxic pollutants of interest; and
- transfer of research results, in usable form, to the user community.

FUTURE TRENDS

Faced with a fixed and unequally distributed water resource and an ever-increasing population, greater and greater water conservation, including reuse, will be necessary as the United States moves into the 21st century. Several regions of the country are already experiencing shortages of surface water. Other regions are experiencing shortages of surface water of the necessary quality. These problems will intensify unless the necessary steps are taken to systematically and effectively manage both water quantity and quality.

There will be increasing public concern about other national needs as well, such as an adequate energy supply, a strong defense, a healthy economy, and a restrained federal budget. The public's overall interest will be in maximizing the quality of life given limited financial and natural resources. This can be achieved only through conscious cost/risk/benefit types of tradeoffs among life's choices of personal needs and comforts, only one of which is a relatively clean and healthy aquatic environment. Growing public sophistication will reduce demands for zero risk technologies and environments. Priorities in the expenditure of public and private funds increasingly will reflect the rate of real risk abatement per unit of investment.

Over the next 20 years and beyond, a much greater emphasis can be expected to be given to considerations of cost-effectiveness in all pollution control measures advocated by the Agency. After having experienced a significant period of high inflation and energy shortages, the populace will be much more cost conscious and public support for further environmental expenditures will be given only where they can be shown to yield commensurate benefits. As a result, greater attention will be given to integrated environmental planning. Not only will there be a greater effort to make tradeoffs between point and nonpoint source controls, but greater consideration will be given to the intermedia transfers of pollutants and associated implications on the effectiveness of goal attainment through control of indirect as well as direct discharges to surface waters. In addition, there will be greater scrutiny at the local level of the national goals suggested by the Clean Water Act at those locations where additional point source control over and above the technology-based level (in concert with nonpoint source and non-source control measures) is needed to meet them. The Agency will be acutely aware of this and must be prepared to defend its position in those instances where it determines the additional level of point and/or nonpoint source control necessary to meet the national goals is feasible and attainable.

This increased concern for cost-effectiveness in pollution control decisions will be accompanied by an increased emphasis on gathering of the information about current and future pollution sources and their impacts as necessary to make these kinds of decisions. Consistent with these concerns over costs, there also will be greater emphasis on more accurately defining water quality requirements for intended uses and on the systematic acquisition of data needed to identify incipient problems and take timely preventive or corrective measures. New problems may be the result of new pollutants entering the environment for the first time, old and familiar ones reentering at excessive rates, or modifications being made in the physical features of water bodies or their watersheds. New pollution problems are likely to result from the wider range of materials that will be required for emerging technologies. Such metals as titanium, gallium, vanadium, niobium, and chromium, as well as coal and oil shale liquids and biologically generated chemical feedstocks, are likely to become much more common.

The problems of ultimate disposal of waste residuals is likely to intensify, as ever-increasing pollutant loads from an expanding population and economy and greater and greater levels of pollution control generate larger and larger amounts of residuals. As a result, available alternatives will be scrutinized more closely, including greater use of the oceans for this purpose. This will result in the undertaking of rather comprehensive assessments of the costs and environmental impacts of alternative disposal policies and is likely to include considerations of dredge spoils as well as waste residuals.

There will be still other pressures brought to bear on environmental protection programs. Various predictions of 21st century problems suggest that, on a global scale, there will be markedly increased environmental degradation. This is expected to result from:

- more serious water shortages because of a relatively fixed supply and an increasing demand; in certain parts of the world shortages also will be attributable to increasing costs of developing new water supplies and maintaining existing ones;
- serious degradation of agricultural soil because of erosion, loss of organic matter, desertification, salinization, alkalinization, and waterlogging; these problems elsewhere in the world still will impact on the U.S. by increasing pressure on the U.S. to meet a larger share of the world's food supply needs;
- continued deforestation, eliminating 40 percent of the remaining standing forest cover by 2000;
- increasing NPS pollution volume in every category; and
- increased levels of metals and pesticides being introduced into the environment.

Thus, the Agency increasingly will feel pressure from two directions: One, for the increased utilization of natural resources to meet human needs; and two, for environmental protection requirements to be risk explicit, justifiable, and implementable with minimal adverse economic impact on society.

WATER QUALITY RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Scientific Assessments	Produce revised or new water quality criteria documents for priority pollutants which identify levels protective of human and aquatic life	▲	▲	▲	▲	▲
	Prepare health analyses for Clean Water Act Sec 301(g) waivers		▲	▲		
Technical Information and Liaison	Produce research summary reports, guides, seminars, and symposia on emerging technologies for the user community	□	□	□	□	□
	Prepare Research Outlook report required by Congress, annual Research Highlights, and Research Program Guide	▲	▲	▲	▲	▲
	Improve and maintain centralized information access and research project tracking system and respond to inquiries	□	□	□	□	□
	Support regional liaison activities	□	□	□	□	□
Monitoring Systems and Quality Assurance	Develop standardized reference measurement methods for priority pollutants (and their impacts)	▲	▲	▲	▲	▲
	Develop standardized toxicity screening tests for rapid identification of toxic hotspots		▲	▲		
	Develop methods for measurement of ionic species of metals	▲		▲ ▲		
	Develop measurement methods for viruses attached to particles in water and sludges	▲		▲		

▲ *Final report, manual or user's guide;* △ *Interim report or manual;* ● *Prototype equipment and report;*
★ *Interim or final criteria formulations;* ○ *Final protocol;* ■ *Continuing effort;* □ *Other, self-explanatory*

WATER QUALITY RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Systems and Quality Assurance	Evaluate and adapt overhead remote sensing techniques	▲	▲	▲		
	Acquire, process, and analyze overhead imagery in support of EPA needs	□	□	□	□	□
	Develop monitoring network design techniques	▲	▲			
	Update and maintain agency-wide quality assurance program	□	□	□	□	□
Health Effects	Compile health effects information on priority pollutants for use in preparation of water quality criteria documents	▲	▲	▲	▲	▲
	Validate health effects criteria for priority pollutants			▲	▲	▲
	Develop water quality requirements for recreational uses	▲	▲			
	Prepare state-of-the-art summary of the application of short-term *in vivo* tests for carcinogenesis		▲			
	Prepare state-of-the-art summary of the application of short-term tests for health endpoints other than cancer		▲			
Environmental Processes and Effects	Compile aquatic life effects information on priority pollutants for use in preparation of water quality criteria documents	▲	▲	▲	▲	▲
	Improve guidelines for generating data about effects on aquatic life in fresh and marine waters		▲	▲		
	Establish guidelines for translating laboratory-derived criteria to field situations		▲	▲		
	Develop toxic pollutant exposure analysis predictive techniques		▲			
	Develop techniques for documenting NPS pollution effects		▲	▲	▲	
	Develop watershed analysis and point and non-point source load allocation predictive techniques		▲	▲ ▲	▲	
	Develop techniques for predicting impacts of dredge and fill operations	▲	▲ ▲	▲	▲	
	Develop techniques for predicting impacts of ocean disposal		▲	▲	▲ ▲	▲
	Conduct long-term exploratory research on basic problems associated with:					
	— intermedia transport of pollutants			▲	▲	▲ ▲
	— identification of ecological effects of pollution			▲	▲	▲ ▲
	— pollution impacts on the marine environment			▲	▲	▲ ▲
	— environmental influences on behavior and toxicity of toxic metals in aquatic systems				▲	
	— identification of benefits from application of lake restoration/protection techniques				▲	

INDUSTRIAL WASTEWATER

Industrial and domestic wastewaters have been discharged into our nation's waterways for many years. By the 1970s, in a number of cases, degradation had progressed so far that aquatic life in many areas, including such water bodies as the Mahoning and Cuyahoga Rivers in Ohio, the Hudson River in New York, and even parts of the Great Lakes, had been severely impaired or, in some cases, virtually eliminated. Of even more concern, however, are drinking water supplies found to contain toxic chemicals of industrial origin. The chemicals find their way into the drinking water supplies as the nation's waters are used and re-used. For instance, water travelling from a river's source to its mouth often passes through areas of both heavy industry and dense population; waters withdrawn to serve drinking water needs of one community can come from waters discharged upstream by industries and other communities.

Over the last decade, the downtrend in water quality has been slowed or arrested and in a few sections of the country even reversed. As pollution controls have been imposed and enforced, the first glimmers of progress toward attainment of the national goals of fishable and swimmable waters have been noted in some hard-hit areas. For example, native species of fish that had been displaced from the Hudson River by pollution are gradually returning. Despite the signs of a turnaround in water quality, we are still far from solving our water pollution problems.

Although progress in cleaning up our country's waters has been uneven and attainment of national water quality goals still lies beyond our immediate grasp, we have taken important first steps through our efforts at industrial pollution control. As noted in the Council on Environmental Quality's Tenth Annual Report, "The fact that our surface waters have not deteriorated further, however, in a period of rising population and Gross National Product, is a victory for the nation's water pollution control efforts and is in no small part due to industrial cleanup of conventional pollutants." Future emphasis, however, will be placed on the control of toxic industrial discharges.

Legislative Background

Control of industrial water pollution is mandated by the Clean Water Act, which provides for a National Pollutant Discharge Elimination System (NPDES). Under this provision, EPA or approved state regulatory agencies issue permits limiting the release of individual pollutants. The control technologies to be used are identified by EPA through effluent guidelines for particular industry segments. The initial set of guidelines and permits supported the achievement of best practicable treatment (BPT), aimed at effective control of conventional pollutants causing biochemical oxygen demand and chemical oxygen demand, suspended solids, and a few specific pollutants of known concern, such as mercury, cadmium, and phenols.

A 1976 consent decree with the Natural Resources Defense Council (NRDC) set Agency priorities by identifying 65 classes of compounds on which the Agency would be required to focus initial regulatory efforts. These pollutants are being addressed in the development of effluent guidelines for defining best available technology economically achievable (BAT) in 21 industrial categories also cited in the consent decree. Where effluent guidelines are not yet published, however, NPDES permits are issued based on the best information available. These "technology-based" standards, which address direct industrial discharges, and pretreatment standards, which describe comparable treatment needs for industrial discharges into municipal treatment facilities, were required by Congress as a minimum level of treatment nationwide. Where additional treatment would be required, as in areas with large numbers of industrial dischargers, case-by-case decisions would be made by the permitting authority such that water quality standards will be achieved in the receiving stream.

Previous Research Activities

When EPA was created in 1970, it acquired a program of ongoing industrial water pollution control research, development, and demonstration from the Department of the Interior's Federal Water Quality Administration. EPA's Office of Research and Development then took responsibility for the research and development program and continued striving for improved industrial wastewater control capability. The major activities consisted of documenting the state-of-the-art of control options and characterizing various industrial wastewater discharges. Other efforts were directed to developing improved and more cost-effective technological solutions. While control technology research and development efforts concentrated largely on conventional pollutants and end-of-the-pipe treatment, even in the late 1960s and early 1970s they began to emphasize the application of water recycle and reuse approaches. Many of the efforts were catalyzed by significant industry participation through cost-sharing of large pilot- and full-scale demonstrations.

The Clean Water Act's mandate for technology-based standards required an extensive research program to support the development of effluent guidelines and pretreatment standards. Certain of ORD's accomplishments have already come to fruition in a regulatory sense—for example, the development of technologies for the recycle and reuse of wastewaters in the pulp and paper, food, and electroplating industries. In the electroplating industry, through the application of EPA-developed technologies, the release of such toxic metals as cadmium and chromium is projected to be eliminated over the next 10 years despite that industry's continued expansion. ORD's efforts in control technology development for the iron and steel, tanning, textile, metal finishing, and mining industries have also been significant.

The NRDC consent decree in 1976 and the Clean Water Act Amendments of 1977 (PL 95-217) added new complexity to the regulation of industrial wastewaters by requiring toxic-specific control requirements. The research program, therefore, in addition to developing new and improved control technologies, also had to develop innovative and cost-effective analytical techniques and monitoring methods for the toxic pollutants identified in the consent decree.

Measurement methods in particular demanded our best efforts, especially for determining compliance of industrial discharges with standards governing multiple toxic pollutants. The high cost of individual chemical or biological analyses and the difficulty in relating individual constituents to specific observed pollution impacts posed the challenge for us to seek alternatives to the measurement of individual contaminants. New emphasis began to be placed on identifying other parameters that could serve, under certain conditions, as less expensive, and perhaps even more meaningful substitutes for detailed pollutant-by-pollutant chemical analysis. For example, increased emphasis has been placed on bioassay-biomonitoring methods (measuring lethal or non-lethal impacts of toxic pollutants on living organisms) as direct measures of the toxicity of effluents and of the reduction in toxicity that can be achieved by various pollution control methods. Other alternatives to pollutant-by-pollutant analysis might include gross measures of various classes of pollutants, such as "total halogenated organics" or "total lipid-soluble material."

In specific support of EPA's regulatory efforts, ORD has recently published a treatability manual for toxic pollutants and also new manuals for analysis and compliance monitoring of the priority pollutants. Finally, in anticipating future needs, ORD has constructed a test and evaluation facility in Cincinnati to evaluate and improve wastewater treatment techniques through pilot-scale experimentation, to debug mobile equipment for on-site field testing at various industrial locations, and to test and calibrate new measurement and monitoring methods.

CURRENT PROBLEMS AND ORD'S RESEARCH PLAN

ORD's industrial wastewater research plan needs to be simultaneously responsive to immediate program office requirements and to the longer-term research implications of problems EPA must face in the future. The program described in this chapter includes the wastewater problems encountered in all of the conventional manufacturing industries, as well as in the specific energy industries relating to electric power generation, coal mining and coal preparation, oil shale mining, oil and gas production, and uranium mining. Discussion of wastewater problems from the synfuels industries, coal conversion, oil shale retorting and gasohol production, is contained in Chapter 2, Energy and Environment.

The "solutions" to industrial wastewater pollution problems do not end with the removal of pollutants from the wastewater. The safe, environmentally acceptable, ultimate disposal of sludges, brines, and concentrates is an essential part of every pollution control system. The very difficult research and development efforts needed to solve these problems are discussed in Chapter 10, Solid Waste.

Industrial wastewater research efforts can be categorized as:

- monitoring systems and quality assurance;
- health and ecological effects,
- industrial source characterization and assessment;
- treatability;
- treatment technology;
- innovative approaches, including recycle/reuse; and
- fundamental research.

The first five of these research areas could, in theory, encompass the entire program. The last two have been added, however, in order to highlight the more innovative and fundamental research activities contained within the program.

Monitoring systems and quality assurance. This research includes development and validation of pollutant measurement methods, preparation of reference analytical samples, and compilation and review of related procedures and protocols specifically for industrial wastewaters. A primary focus of this work is to provide certified monitoring and quality assurance methods for EPA's regulatory and enforcement programs, as well as for other research and development efforts.

The monitoring portion of the program is influenced strongly by the needs of the Agency's programs for permits, enforcement, and, to a lesser degree, effluent guidelines. A host of organic and inorganic chemical species now of concern include pesticides, polycyclic aromatic hydrocarbons, and trace metals. In response to program needs for these species and others, existing analytical methods are being improved and new ones are being developed. Of longer-range interest are development of methods using alternate monitoring parameters, standardization and certification of bioassay/biomonitoring methods, and adaptation of analytical techniques for on-line monitoring and process control.

The work on quality assurance focuses on improving the dependability of making pollutant measurements, an area of prime importance to EPA's regulatory and enforcement functions. Sample collection is the first step in performing an analysis and often determines whether an analytical result truly represents conditions in the sampled wastewater. Therefore, methods for sampling are being reviewed and improved. Another important aspect of the quality assurance program is the development, maintenance, and distribution of a supply of reference samples. Prepared to known concentrations of specific pollutants, these samples are used as a check on analyses performed at laboratories throughout the country. The quality assurance research also includes the development of statistical and other data-handling techniques.

The monitoring and quality assurance research efforts also provide direct technical support to EPA's regulatory and enforcement programs. This includes assistance with implementation of the NPDES program and an Agency-wide quality assurance effort for assuring monitoring data uniformity. Other support is for quite specific EPA legislative requirements.

Health and ecological effects. Research into the effects of waterborne pollutants on human health and on the overall environment is essential to determining the requirements for industrial water pollution control. Specific activities within the industrial wastewater research program are concerned with (1) the development of bioassay/biomonitoring methods for industrial effluents and (2) the establishment of criteria for safe industrial wastewater recycle/reuse. Most of ORD's health and ecological effects work is conducted, however, under the water quality research program (see chapter 12, Water Quality).

The industrial wastewater program's bioassay/biomonitoring methods research is coupled closely with work on preparing a manual for a toxicity reduction plan in support of water enforcement activities. This work is in anticipation of the increasing use of "toxicity units" as a compliance parameter in NPDES permits. Data are now being compiled on the effectiveness of various treatment technologies to reduce the toxicity of industrial effluents. Further development and refinement of the bioassay test methods now being used and collection of data on more types of industrial wastewaters is planned. This research also supports EPA regulations called for under Sections 308 and 402(a)(1) of the CWA.

The recycle/reuse studies aimed at establishing reuse quality criteria are currently concerned with the health-related aspects of reusing water in the food processing industry. Specific industrial categories under investigation are fruit canning and poultry processing.

Industrial source characterization and assessment. To properly understand and evaluate sources of industrial pollution, a data base is being established to characterize and describe various industrial categories, their manufacturing processes and wastewater streams, the expected pollutant concentrations in their wastes, and possible options to treat their wastewaters. To confirm literature data and expert predictions, actual sampling and analysis of the wastewaters at representative industrial sites must be conducted. The resultant data base will provide the basic foundation for establishing research and even regulatory priorities and guiding longer-term Agency efforts.

Industrial source characterization and assessment research is necessary both to the proper and intelligent planning for the development and improvement of control methods and to the comprehensive formulation of effluent limitation guidelines for existing and newly emerging industries. Emerging energy technologies in particular must be closely examined because of the key role they will play in the U.S. in the future. While most energy technology assessment activities are described in the Energy and Environment chapter, work under the industrial wastewater research program will encompass, as stated before, examination of effluents from conventional power plants, coal mining, coal preparation facilities, oil shale mining, oil and gas production, and uranium mining.

Our characterization and assessment research focuses on total environmental impacts of an industry. That is, cross-media impacts (for example, from water to land to air) must be identified since pollution control in one medium may lead to additional control needs in another.

Data base development will continue in order to provide a comprehensive environmental characterization of key U.S. industries. Ongoing efforts to complete and maintain data bases on the pesticides and organic chemicals industries are crucial to EGD's regulatory initiatives in those areas. Another type of data base support activity is aimed at the systematic compilation of information on the chemical engineering unit processes used as the building blocks for organic chemicals plants. Here, an attempt will be made to predict likely by-products, side-products or other impurities, particularly those of a toxic or hazardous nature, which may appear in the wastewater of various chemical manufacturing plants.

Treatability. The treatment of industrial pollutants is based on their susceptibility to removal, destruction, or detoxification by various physical, chemical, or biological processes. Knowing how such pollutants respond to various treatment alternatives is, therefore, of fundamental importance in preparing effluent and pretreatment guidelines and issuing discharge permits. Our research is obtaining, analyzing, and compiling data on pollutant treatability, with specific emphasis on toxic compounds. Because toxicity reduction is of increasing interest, "toxicity units" are now being used as an additional parameter for assessing the effectiveness of various treatment options. Data on the treatability of toxicity by various control technologies is being compiled.

The treatability studies being conducted range from the development of theoretically based predictive models of pollutant treatability to the conduct of experimental evaluations of specific pollutant removal by various processes. The predictive models might, for example, utilize chemical structure/activity relationships to predict the removal or destruction of pollutants by various treatment mechanisms. The laboratory treatability studies, on the other hand, experimentally determine the removal characteristics of specific toxic pollutants from the wastewaters of a variety of industries including pesticides, organic chemicals, iron and steel, and energy minerals mining. An important technique in the experimental program will be the construction and application of mobile treatment modules for on-site evaluations at actual industrial locations.

In 1980 a major output of our treatability research program was the publication of the first edition of the treatability manual—a set of volumes presenting data on the removal, destruction, or detoxification of a wide range of compounds, operational information for existing control technologies and their design criteria, and capital and operating costs. The manual will be updated on a regular basis, eventually incorporating mathematical models of treatability as this capability becomes available.

Treatment technology. Our treatment technology research encompasses development of new or improved technologies for separating, destroying, or chemically modifying troublesome contaminants in industrial wastewaters. Research in this area responds to demands created by stricter discharge requirements, new or newly discovered pollutants, the trend to recycle and reuse effluents, and the need to minimize cost and energy consumption in meeting national pollution control needs. The effort also recognizes the need to achieve effluent qualities based on meeting ambient water quality requirements for discharges into rivers, streams, and the groundwater where the level of control achievable under BAT is inadequate.

To assure the necessary lead time to develop, demonstrate, and commercialize new methods, novel technologies and novel applications of known technologies will be evaluated in bench-, pilot-, and full-scale installations. Included in this area is improved operation and maintenance of industrial waste treatment facilities. As has been recognized in the municipal area, many industrial sources are not controlled up to the treatment facility's potential because of operational and maintenance failures. One area of increasing interest is the adaptation of automated pollutant measurement methods for on-line control of treatment processes to improve the consistency and reliability of their performance.

Our research focuses both on specific industry-by-industry treatment needs and on generic treatment techniques of broad applicability. Among the industries being addressed currently, and with respect to their nearer-term activities, are organic chemicals manufacturing, textile manufacturing, iron and steel production, smelting of non-ferrous metals, and metal finishing. In deciding where particular emphasis should be placed, we have not only considered the regulatory schedules of EPA's program offices, but we have also weighed the presence or absence of potentially health-threatening pollutants and the ability of the industry itself to fund the necessary research and development to resolve its own problems. Special emphasis has been placed on economically marginal industries, such as electroplaters and tanneries, in an effort to reduce the economic and social impact of regulation whenever possible.

The energy industries for which treatment technology studies are being conducted include coal and oil shale mining and enhanced oil and gas production. In these areas, as with the synfuel and other energy-related industries, industrial activity is expected to accelerate considerably during the next decade as part of the nation's effort to expand the utilization of domestic energy sources. Our research must anticipate this trend. As for other energy-related efforts, a technique is being developed for conventional power plants to reduce the cost of treating cooling water to remove chemical additives used for preventing the fouling of heat transfer surfaces by biological slimes. Also, the wastewater treatment needs for uranium mining and for tar sands development are to be evaluated. Of the energy industries included in this area, the mining of oil shale and tar sands is expected to present unique wastewater treatment problems arising from an anticipated different set of organic pollutants in these wastewaters. This may require different treatment approaches from those used, for example, in either coal mining or petroleum refining.

Since most treatment techniques have application to several industries, generic treatment studies are included in our program. That is, various processes are being evaluated and developed for general classes of pollutants rather than for treatment of specific industrial effluents. Treatment technologies to be examined include biological degradation, membrane processes such as reverse osmosis, and activated carbon and resin adsorption. In general, new treatment techniques will first be examined generically before application to specific industrial wastewater is attempted. In these generic studies, recognition will be given to the inescapable fact that pollutants not destroyed or detoxified by treatment are simply transferred from the wastewater to a sludge or other concentrated residue. These results must be disposed of in some fashion and, if "hazardous," must be handled in compliance with various regulations under the Resource Conservation and Recovery Act. Therefore, a goal of our research will be to prevent or minimize the transfer of hazardous substances to sludges in the first place. These studies include the treatment capabilities of municipally owned treatment plants that receive industrial wastewater and support development of pretreatment standards for the various industrial categories.

Another concept under study is centralized treatment of industrial wastes, in which a variety of industrial wastewaters, either from one plant or from several, are sent to a treatment facility owned jointly or by a separate operator.

In meeting direct regulatory needs, our treatment technology research will be used in the formulation of final effluent limitation guidelines for textile mills and tanneries, both to be promulgated in the near future. Other industry-specific regulatory efforts include effluent guideline development for iron and steel manufacturing, steam-electric power generation, nonferrous metals manufacturing, coal mining, organic chemicals production, pesticides production, and the electroplating industry.

Innovative approaches, including recycle/reuse. This research goes beyond the more traditional approaches for dealing with industrial pollution. Main objectives for which truly innovative approaches may be required include high efficiency control of specific toxic compounds and attainment of the zero-discharge goal of the Clean Water Act. Difficult research challenges such as these might, for example, be approached by applying recycle/reuse concepts or by changing manufacturing processes or raw materials as opposed to just pursuing more efficient end-of-pipe treatments.

Recycle/reuse is becoming a more and more attractive alternative in industry as competition for resources such as energy and water supplies increases. In anticipation of this trend, efforts have already begun to identify the industries for which recycle/reuse appears most feasible and to support key projects aimed at demonstrating recycle/reuse as a control method for toxic discharges. Industrial and other decision makers are beginning to recognize that the cost of renovating an industrial wastewater stream for reuse is often less than the cost of cleaning a discharge to a quality suitable for release. However, accurate and complete information is needed about the quality levels renovated water must meet for various recycle/reuse purposes—including industrial, agricultural, recreational, and even municipal reuse possibilities—and practical, cost-effective and energy-conserving wastewater renovation techniques must be developed and brought to the point of commercial application. Recycle/reuse options are being considered for textile manufacturing, metal finishing, iron and steel manufacturing, petrochemicals and pesticides production, and petroleum refining. Ultimately, case histories of successful recycle/reuse applications will need to be documented.

We shall increasingly consider non-treatment control alternatives as we move through the 1980s. We hope to motivate other researchers, especially those in industry, to examine process change, raw material substitution, synthesis (that is, product design to deliberately include non-toxicity, high adsorbability, biodegradability, etc.), and other methods of control that may provide better or more economical solutions than end-of-the-pipe waste treatment.

We will encourage industry and assist where funding permits in developing and demonstrating less polluting manufacturing concepts. These concepts may range from improved process retrofits to alternative, entirely new manufacturing concepts. The concepts to be considered could, for example, arise from fundamental research on innovative technology at EPA's Industrial Waste Elimination Research Center. Or, at the other end of the spectrum, alternative processes may have already been used in full-scale practice in some kind of service, perhaps even in a foreign country. Here the need may be to adapt and demonstrate the technology for American industrial practice to assure its technical and economic soundness. The metals industry is a particularly good example. Installations in Europe and Japan were either greatly expanded or rebuilt after World War II, using more recent technologies than many U.S. installations which date back to the pre-World War II era. Foreign technology in general also has had to be more energy-conserving because of generally higher fuel costs. An example of useful foreign technology is the Swedish ion exchange process that can achieve complete recycle of bleach plant effluent in pulp and paper manufacture. The process is capable of removing 95 to 99% of chlorinated phenols and 90% of color—and all this with a net energy saving over conventional control methods.

As for other innovative approaches, we plan to evaluate and model selected chemical reactions used broadly in manufacturing various chemicals in order to predict, from an understanding of the chemistry involved, the occurrence of toxic by-products or side-products which might appear in the wastewaters produced and then to identify possible process changes, raw material substitutions, or other techniques that could eliminate or minimize the generation of the toxic constituents. Another possible approach is to redesign chemical products so that they are less polluting, more readily treatable, or less persistent in the water environment. The conversion of hard to soft detergents some 15 years ago is a good example of this approach. As non-treatment alternatives are identified, the optimum balance of treatment and non-treatment alternatives used in combination will also be established.

As previously described, methods are being developed for utilizing toxicity measurements in regulatory and enforcement actions. A toxicity reduction plan manual is being written to explain to industry and to regulatory personnel how to quantify wastewater toxicity, track down and pinpoint the source or sources of toxicity in an industrial plant, and reduce the toxicity of the wasewater effluent to acceptable levels. The Office of Water Enforcement has specifically requested completion of the first edition of the manual before thir next round of NPDES permitting beginning in 1981.

Finally, explicit regulatory support is provided to Agency efforts to evaluate technology proposed by industry as innovative under Section 301(k) of the CWA. The Agency must determine whether the proposed innovative technology, which allows significant cost savings, is superior or equivalent to BAT. ORD researchers will assist in these determinations.

Fundamental research. A future outlook for research would not be complete without mention of longer-term fundamental research efforts. Support of fundamental research is needed not only to develop the knowledge base for solving the next generation of industrial water pollution problems, to allow intelligent extrapolation of present knowledge to new applications, and to increase our ability to react to unexpected events, but also to promote the development of experienced experts upon whom EPA and others can depend.

Clearly, more fundamental knowledge is needed on the mechanisms and kinetics of generation and destruction/detoxification of industrial pollutants, on the mechanisms of separation of such pollutants from water, and on the detection and identification of contaminants in wastewater. Our goal should be to achieve sufficient basic understanding of industrial water pollution problems and alternative solutions so that reliable predictive judgments can ultimately be made as to the minimum-cost approach for controlling each type of problem encountered.

EMERGING PROBLEMS AND ASSOCIATED RESEARCH NEEDS

The Office of Research and Development must take the lead within the Agency in identifying and responding to impending research needs associated with emerging environmental problems. Certain industrial problems of rising concern during the remainder of this century are already coming into focus. These will influence our research directions even over the next five years.

Quite naturally, several of the general trends already discussed in the previous section will continue on at least through the year 2000. These include increasing industrial wastewater recycle/reuse, increasing attention to process change and new process selection as ways of reducing the generation of troublesome wastewater constituents, and increasing application of bioassay/biomonitoring methods to measure pollution and to regulate pollution in terms of toxicity units. We also see a number of more specific trends increasing in importance. Some are significant even now while others will have their impact in 5, 10, or 15 years.

These trends include:

- advancing environmental measurement and assessment capability;
- increased importance of intermedia impacts and controls;
- approaching the assimilative capacity of waterways;
- application of centralized waste treatment;
- recovery and reuse of natural resources;
- mining and processing of lower-grade ores;
- accelerated mining of coal and other energy resources;
- utilization of synfuel-derived refining and chemical feedstocks;
- utilization of new resources and manufacture of new products; and
- commercialization of genetic engineering technology.

Advancing environmental measurement and assessment capability. Advances will inevitably occur in our ability to identify and measure pollutants and to pinpoint and understand their effects on man and the environment. Improvements in wastewater pollutant monitoring and in understanding aquatic toxicology and human health effects will undoubtedly lead to identifying new pollutants, detecting them at lower concentrations, and better understanding their hazards, both singly and in synergistic combinations. With the accumulation of more and more environmental data and with better mathematical modeling of environmental and health-related phenomena, our abilities in the area of complex environmental problem analysis will also improve. Because of the growing public awareness of the effects of environmental pollution, especially on health, public pressures to prevent toxic materials from entering the environment are expected to continue to build. The obvious dilemma is: How can we simultaneously meet these pressures, allow industrial and economic growth, and meet energy independence goals? A clear part of the answer must be development and utilization of "minimum cost" (including energy costs) industrial pollution control options. The only route to this goal is research and development.

Increased importance of intermedia impacts and controls. As environmental controls become more stringently and widely applied, the impacts on one medium of controls applied to protect another medium will have increased significance. Close attention will have to be paid to these cross-media impacts in order to arrive at a best overall solution to environmental problems. For example, industrial wastewater treatment designers will have to examine more closely the air pollution implications of transferring volatile organic compounds, including volatile toxicants, to the air when aeration or air/steam stripping techniques are applied in wastewater treatment. They will have to consider the air pollution impacts of reactivation or disposal of spent activated carbon containing possibly hazardous pollutants that have been removed from industrial wastewaters. Similarly, those engaged in air and solid/hazardous waste pollution control activities must become aware of possible water pollution problems they may cause (for example, the generation of highly potent leachates from landfilling operations) if their efforts produce wastewaters ultimately destined for discharge to surface or ground waters.

Approaching the assimilative capacity of waterways. Despite our attempts to achieve zero discharge, that goal probably cannot be met until well into the 21st century. Therefore, our society will continue to rely to a significant extent on the assimilative capacity of the natural environment in its waste disposal practices. It is recognized that all treated wastewaters contain a residual fraction of contaminants that were not removed by whatever control methodology may have been employed. Generally speaking, it is also recognized that application of current state-of-the-art control capability, if not augmented by technological advances, will result in gradually increasing pollution loads to certain receiving waters. This will occur simply because of increasing raw waste generation as the result of expanding population, increased industrial activity, and continued urbanization coupled with the limit on degree of control currently achievable.

It seems clear that many of our nation's waterways will be stressed beyond tolerable bounds; that is, more and more will evolve into water quality-limited situations, as the 20th century draws to its end. Our outlook in this area needs to include awareness of this situation and to begin to factor into our plans a recognition of where water quality pressures will occur first and what advancements in control capability are necessary to cope with them.

Application of centralized waste treatment. The concept of centralized treatment of single-type and mixed industrial wastewaters is expected to take on increased importance as pollutant removal requirements become more stringent, good water supplies become more scarce, and recycle/reuse becomes practical to a much greater extent. The level of technology and technological expertise required to maintain and operate increasingly sophisticated treatment trains and the economics of larger-scale operation will demand more centralization of activities for the most cost-effective wastewater management. Therefore, anticipated is the construction of more industrial parks—complexes in which industrial plants of one or more types are co-located in order to take advantage of both centralized treatment facilities and wastewater reuse options and energy recovery. Research planning must begin to take this trend into account.

Recovery and reuse of natural resources. Another emerging trend which should influence our research activities before the year 2000 is the recovery and reuse from discarded products of an increasing number of recoverable resources. Already such materials as paper, oil, and aluminum are being recycled to a limited extent. As resources become more scarce and the cost and energy burdens of natural resource extraction become greater, the associated wastewater-generating activities will most certainly intensify.

Mining and processing of lower-grade ores. As it becomes accepted that our conventional energy resources are limited, it is also being realized that the sources of metals and other non-energy minerals on this earth are finite. In addition, a high percentage of some of these materials is now obtained as imports from foreign countries. These metals and minerals are the basic components of many of the products of commerce of this country; they are essential to our economy. As the ores for metals and minerals come into short supply, successively lower grades of ores will have to be exploited. As this is done, wastewater problems will increase, both in volume and complexity of solution.

Accelerated mining of coal and other energy resources. As the nation moves to reduce its dependence on imported sources of energy, extraction of energy from domestic sources will significantly increase the pressure on the environment. The vast domestic reserve of coal is the prime candidate for helping the nation to meet its near-term energy needs. By 1995 coal production is projected to be almost three times what it is today. In the West, this will mean extensive surface mining of coal on a scale even more massive than current operations. Where the coal seams are closely associated with, or actually are, aquifers, coal deposits will be extracted by various surface mining techniques, often with mine drainage having to be pumped out for surface disposal. In the East, the opening of new surface and underground mines and re-opening of old mines will draw renewed attention to the problems of acid mine drainage. Other problems associated with processing the additional wastewaters from existing and new coal preparation facilities will arise, particularly as new techniques for coal cleaning are developed. Before 1990 we can expect coal to be transported by slurry pipelines, with the attendant need to dispose of slurry water.

The large-scale utilization of new energy minerals such as oil shale, tar sands, and lignite is in its earliest stages in this country. These energy sources will very likely begin to come into their own during the next decade, bringing with them a unique set of environmental problems.

Finally, with increased growth of nuclear power, the uranium mining industry will necessarily expand, causing greater demands for environmentally acceptable methods for the mining and milling of uranium ores.

Utilization of synfuel-derived refining and chemical feedstocks. Present predictions indicate that before the turn of the century, movement away from petroleum-based feedstocks should begin to take place in the refining and chemical industries. It is difficult to foresee exactly which industries will be affected, and although economic considerations would be the determining factors, it is likely that remaining oil and gas reserves will be used primarily for the industries where product quality and/or purity is most critical. Synfuel-derived feedstocks will then take up the slack in demand, presenting, most probably, more severe pollution problems than at present, particularly for users of the lower-grade synfuel feedstocks.

The increased environmental concern results from the different chemical compositions of the basic raw materials to be used and from the processing necessary to produce appropriate feedstocks. For example, the synfuel conversion processes using coal, oil shale, and other energy minerals generally involve highly reducing conditions. This is additional pre-processing required for synfuels as compared to petroleum only refined conventionally. The result is that a wide variety of high-molecular-weight organics, reduced sulfur compounds, and other potentially toxic compounds can be formed, presenting a different array of pollutants than has been dealt with in the past. Solvent-refined coal in particular gives liquids high in aromatic compounds. Even an alcohol feedstock produced from fermentation has the potential, under partial oxidative conditions, to form acetaldehyde, which is listed under the Resource Conservation and Recovery Act as a compound whose presence would cause a waste to be declared hazardous.

It is recognized, however, that the initial synfuels mining and production steps will most likely have the most significant environmental impacts. Nonetheless, the downstream refining and chemical processes that are slated to use the synfuels feedstocks should be reexamined periodically as the industry matures.

Utilization of new resources and manufacture of new products. History teaches that the chemical industry, among many others, will continue to develop and produce new products that will have undesirable environmental implications at some point between their production and their ultimate end. During the next two decades, this growth of new products—and of their associated problems—will undoubtedly accelerate as industry begins to respond to the pressure of higher energy costs, the need to use new raw materials, the increased population, and continuing desires for an enhanced quality of life.

One example of what will result from our energy problems is reasonably large-scale production of some type of electric car. This product must, in turn, be based upon the manufacture of a new and more efficient battery to power it; and from this, a whole subset of new industrial activities may be built up to provide for the cars and their power plants. Many of the wastewater problems and their solutions will be familiar, but many may be ones we have not faced before. As one example, what would be the environmental problems of widespread manufacture, use, and disposal of rechargeable organo-alkaline earth batteries?

New pesticides, drugs, polymers, and specialty chemicals of many kinds will undoubtedly be produced both by conventional processes and, in some cases, by new methods such as photochemistry utilizing advanced laser technology. Our industrial wastewater research must maintain an awareness of such developments and, ultimately, must provide an appropriate foundation for EPA's action in these areas.

Commercialization of genetic engineering technology. An entirely new industry will develop during the 1980s and 1990s—genetic engineering. Commercial ventures have already been initiated for the production of bacteria and other living organisms that are tailor-made for specific purposes. While the field of recombinant DNA technology is just in its infancy, even our present industrial wastewater programs have projects under way and planned for the development of tailored microorganisms for microbiologically degrading pollutants. In other words, the ability to engineer living organisms to perform certain functions or produce certain products will provide a new and potentially powerful tool with which to solve industrial wastewater pollution problems. We plan to use this new tool.

This emerging industry, however, may present some of the most rigorous challenges to industrial pollution control ever encountered. The wastewaters from this industry could contain a diversity of genetic material possibly presenting unique health and environmental hazards. For the first time, for example, a man-made industrial waste discharged to the environment might not only persist but reproduce itself. The potential environmental problems associated with this kind of industrial activity deserve serious investigation and could present unique pollution control challenges.

FUTURE PROBLEMS

It is almost impossible to accurately project the major new industrial water pollution problems beyond the next 20 years. We can still anticipate, however, certain broad trends that should influence our industrial wastewater research program after the year 2000. Probably all of the issues discussed in the section on emerging problems will, if they were valid predictions, continue to represent important factors as we enter the 21st century. In fact, the major trends that will influence the environment in this country after the turn of the century will probably still be the familiar ones of energy and raw material cost and availability—to which could be added pressure to provide food and fiber for the expanding population.

One direction that could be taken is a shift to a solar-generated hydrogen-based energy system. The environmental implications of this option are probably the least serious of the many directions in which the energy problem could drive us. However, we could be faced with a massive industry for solar photovoltaic cell production with the environmental problems inherent in the mining and production of new materials that frequently contain toxic metals, etc. With hydrogen, metal hydrides are currently thought by many to be the most likely storage mechanism for transportation and other uses. Again, a large new industry with inherent environmental problems would have to be developed to produce, use, service, and dispose of the hydrides or their alternatives. These reflect but some of the future environmental issues that might develop with what is probably the most environmentally benign of all of our future energy options. The problems resulting from a thermonuclear, magnetohydrodynamic (MHD), or other energy base are probably much more complex and could be more difficult to deal with.

The United States is a long way from being a mineral-poor country. However, it is an equally long way from being as rich in cheaply extracted minerals as it was 100 years ago. The mineral-availability problem will accelerate to the point that early in the next century we will be looking at mineral sources quite different from those used today. Ocean mining, for example, may well become a common technique, which will have obvious implications for water pollution. Also, we will probably begin to look at former waste dumps as "mine sites" from which we can recover the metals and other materials from the sludges and residues we are putting in landfills today. Disturbing such sites would create difficult pollution control problems.

Oil, our major source of cheap organic raw material, will become much more expensive and will probably be diverted to higher and higher value products, with synfuel-based feedstocks satisfying less critical product demands. Coal, oil shale, tar sands, lignite, and biomass will become the source of relatively cheap organic raw materials. Each of these sources has environmental problems compounded by scale of use and will present a spectrum of potential environmental insults.

With world and U.S. population growing, we will continue to expand our agriculture program to meet domestic needs and to continue our food and fiber exporting. This will continue to apply pressure to all industry and the environment as more land goes into production, more fertilizer and pesticides are needed, more food must be processed, more pulp and paper is made, and so forth. The advantages of relatively available and inexpensive land and separation of developed and undeveloped areas will rapidly disappear, complicating and compounding environmental insults.

In Summary

All of the ongoing, planned, or currently considered efforts, both fundamental and applied, are dependent upon continuing interplay with and feedback from the Agency's regulatory programs and regional offices. Similar interactions with industry and university experts who will often be able to provide insights and experiential knowledge from their own unique perspectives are also essential. These communication linkages will be nurtured and supported to help assure maximum quality, relevance, and objectivity to our research efforts.

INDUSTRIAL WASTEWATER RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Systems and Quality Assurance	Develop and certify improved pollutant measurement methods for organic and inorganic pollutants	○	■	○	○	■
	Develop or review new or existing monitoring procedures and protocols for specific pollutants in industrial wastewaters	○ ▲		○ ▲		○ ▲
	Develop monitoring methods utilizing alternate monitoring parameters		○		○	○
	Standardize and certify bioassay/biomonitoring methods			○ ▲	○	▲
	Develop analytical protocols for resolving the pollutant composition of complex industrial discharges, including both non-volatile compounds and non-extractable polar compounds	△	△	○	□	▲
	Carry out quality assurance programs including the preparation and distribution of analytical reference samples	■	▲	■	▲	■
	Develop chemical/biological techniques for on-line monitoring and process control			▲	○	●
Health and Ecological Effects	Develop bioassay/biomonitoring methods for industrial effluents	△	★ ▲	■		
	Establish health criteria for the safe recycle/reuse of industrial wastewater	▲	■	★	★	★
Industrial Source Characterization and Assessment	Characterize and assess wastewater discharges from process and manufacturing industries to identify pollution problems (from conventional, modified or new technologies)	■	△	▲	▲	▲
	Provide industrial data bases in direct support of effluent guideline preparation	▲	▲			
	Characterize and assess wastewater discharges from power plants, energy mining, coal preparation, and oil and gas production	▲	▲	▲	▲	▲
	Identify potential cross-media impacts of industrial wastewater treatment	■		■		■
	Compare the effectiveness of technology-based vs. ambient water quality-based control strategies for meeting ambient water quality goals		▲		▲	
Treatability	Publish revisions and supplements to the Treatability Manual for control of toxic pollutants	■	■	■	■	■
	Determine treatability—of new pollutants or for higher removal of previously identified pollutants	△ ▲	▲	▲	▲	▲
	Analyze, classify, and correlate treatability data and develop methodology for predicting treatability	△ ▲	△ ▲	■		

INDUSTRIAL WASTEWATER RESEARCH PLAN

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR				
		81	82	83	84	85
Treatment Technology	Develop new and/or more cost-effective industrial wastewater control methods	● ▲	● ▲	●	●	● ▲
	Evaluate generic control technologies for removal of specific pollutants or classes of pollutants	● ▲	● ▲	■	▲	●
	Develop methods for pretreatment of industrial wastewater to be discharged to municipal treatment plants	● ▲				
	Determine energy usage and cost-effectiveness of industrial wastewater control technology	▲	▲	▲		
	Assess effects of O&M procedures on control systems performance and develop improved methods		▲	▲		
Innovative Approaches Including Recycle and Reuse	Evaluate and develop recycle/reuse technology for specific industries and for generic industrial applications	▲	● ▲	▲	■	▲
	Develop and demonstrate non-treatment control methods, e.g., process and product modification, raw material substitution, by-product recovery, chemical modification of toxic pollutants, water- and energy-conserving technologies, etc.		■	▲	▲	● ▲
	Publish toxicity plan manuals to provide guidance on control technology selection and monitoring	△	△	▲		
	Assess and evaluate concepts for centralized treatment of industrial wastewater			▲	▲	▲
	Develop improved Best Management Practices for conventional and selected energy industries	▲	▲		▲	
Fundamental Research	Explore new chemical and biological analysis techniques for monitoring pollutants and measuring treatability	▲	▲			
	Examine fundamental mechanisms of pollutant generation, removal, and destruction to enable the identification of new or improved methods of control	▲	▲	▲		
	Explore potential environmental impacts and possibilities for new control techniques from emerging fields of scientific activity, e.g., genetic engineering	■	▲	▲	▲	

▲Final report, manual or user's guide; △Interim report or manual; ●Prototype equipment and report;
★Interim or final criteria formulations; ○Final protocol; ■Continuing effort; □Other, self-explanatory

MUNICIPAL WASTEWATER POLLUTION CONTROL AND SPILL PREVENTION

Over 16,000 publicly owned wastewater treatment works currently exist in the United States. These facilities treat the domestic sewage of over 164 million individuals as well as a large amount of industrial wastes discharged into municipal sewers. Discharges from public works amount to nearly 26 billion gallons of treated wastewater that are added to our nation's waterways and land surfaces each day. Urban runoff—the washings from our streets, roofs, and other surfaces during rainfall and snow-melt periods—contributes another 16 billion gallons of contaminated water each day.

Detailed investigation of the impact of urban wastewater discharges over many years has shown that, when poorly managed or untreated, they have created serious human health problems and other adverse environmental impacts. Diseases such as cholera, typhoid fever, and other enteric infections have been transmitted by urban wastewater discharges. Receiving waters into which discharges have flowed have been depleted of oxygen, overfertilized with nutrients and contaminated with toxic materials, causing death or severe damage to aquatic life and drinking water supply deterioration. In recent years, organic compounds that pose potentially severe threats to public health have been found in both municipal and industrial wastewater; a number of these compounds are toxic, some carcinogenic. However, there is not enough information to accurately define the current concentration of these materials within the waterways or to predict their future environmental significance.

Legislative Background

The origins of the federal wastewater research program can be traced to studies of several U.S. waterways in the early 1900s. The current program was initiated in the early 1950s, when the U.S. Public Health Service established the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. This center's basic research greatly advanced understanding of the causes of and potential cures for water pollution problems. From the middle 1950s through 1970, the passage of permanent federal water pollution control legislation—notably, the Federal Water Pollution Control Act (FWPCA) in 1956—gave impetus to research that substantiated the need for improved treatment technology. The Taft Center determined that such improvement and development in both the industrial and private sectors in the United States was going to demand increasingly sophisticated techniques for assessing water pollution problems and engineering solutions. It focused its research, therefore, on the development of methods for achieving very high levels of pollutant removal. Development of those methods, appropriately called "advanced waste treatment" (AWT), has made the United States a world leader in water pollution control research and development.

Over the years, the federal law concerning water pollution has been changed a number of times, but the most significant impacts on the nature of the municipal wastewater research program have resulted from two factors: (1) the requirement of the 1972 FWPCA amendments that secondary treatment technology be installed in all publicly owned treatment works (POTWs) in the country, and (2) failure to appropriate increasing amounts of federal funds to meet growing costs.

The FWPCA was amended in 1977 by the Clean Water Act (CWA), a piece of legislation that recognized the need to reduce the high cost of wastewater treatment and still improve the performance of treatment technology. As a result of the Act's passage, the construction grant program for sewage treatment works adopted a national campaign to construct treatment works that use innovative and alternative technology for reducing energy and capital costs. The CWA also required that technological alternatives to the more conventional treatment approaches be considered for incorporation into the federal construction program.

CURRENT PROBLEMS AND RESEARCH EFFORTS

The current municipal wastewater research and development program is a broad-based effort designed to provide the technological advances and technical backup needed for EPA's construction, enforcement, and area-wide planning programs. Basic authorization for research and development—including specifically identified areas of technology—is contained in the FWPCA, as amended. Each research area was selected because of the need for more cost-effective technology that can be applied across the nation to bring about acceptable environmental solutions.

Within the framework of the FWPCA and the support requirements of the various programs administered by other offices within EPA, 10 specific technological areas are the subject of research and development activities that are working toward a solution to municipal wastewater pollution problems. These are:

- treatment process development;
- control of toxic materials;
- sludge management;
- treatment works operation and design;
- land application and aquaculture techniques;
- urban runoff;
- small wastewater flows;
- innovative and alternative technology;
- health effects; and
- monitoring systems and quality assurance.

Treatment process development. Extensive use of the chemical treatment methods for removing the nutrient material, phosphorus, from treatment works effluents prior to their discharge is having a positive effect on the improvement of the Great Lakes' water quality.

Pure oxygen instead of air is now used to aerate sewage in a large number of facilities having high loadings of organic materials. This practice has enabled treatment works to process more wastewater at less capital cost for upgrading capacity and performance.

To protect public health, a number of states require that wastewater be disinfected after treatment and before discharge into surface waters. However, chlorine, the commonly used disinfecting chemical, can have adverse effects on the environment. Investigation of alternatives to chlorine has resulted in development of successful ozone and ultraviolet light disinfection processes. Several full-scale systems using these processes have been built and are undergoing evaluation.

In addition, research is continuing to develop ultraviolet-dose control technology and to assess problems associated with regrowth of organisms after disinfection (aftergrowth). A wastewater disinfection design manual is being prepared and an international symposium on wastewater disinfection is planned for 1982. This will complete the research program in this area.

Control of toxic pollutants. This area of research aims at developing control options and technologies that will prevent or control the discharge of toxic pollutants into the environment from municipal sewerage facilities. The program is designed to identify the sources of toxic pollutants in municipal wastewater systems, investigate conventional and/or new treatment technologies, study methods for controlling discharges at the source, and provide cost and systems analyses of the various approaches.

Several areas related to characterization and treatability of chemicals are being investigated. Evidence to date suggests that a major mechanism for removal of synthetic organics by biological processes is accumulation in the biomass (sludge) at enhanced concentrations. The concentrations in the sludge, two or three orders of magnitude higher than the influent, are sufficient to merit research on the effect of these organics on the various ultimate disposal choices for sludges.

Sludge management. One of the most pressing problem areas relating to wastewater pollution control is the need to determine beneficial uses for, treatment of, and disposal of the residual materials (sludge) that remain after treating wastewater. The EPA is charged with the responsibility for regulating the use and disposal of municipal sludges under Section 4004 of the Resource Conservation and Recovery Act (RCRA) and under Section 405 of the Clean Water Act. In discharging that responsibility, EPA has become aware of many problems associated with the beneficial use of sludge. Of particular national concern are the potential health impacts of heavy metals (particularly cadmium) that are found in the sludges and that find their way to humans through the food chain when sludge is applied to the land. The microbiological contamination of sludges, due to their origin, is of serious concern, as are the complex organic compounds also incorporated into the sludge. Emissions from sludge incinerators or incinerators which burn both sludge and municipal solid wastes have recently become an issue when incinerators are proposed as a land-based disposal option.

As the United States moves toward fulfilling the national requirement for secondary treatment of all municipal sewage discharges, these problems and issues will become more important and difficult to solve because secondary treatment removes more of the materials in question and thus produces more sludge than does simpler (and less effective) technology. Therefore, the sludge problem will grow, creating new and larger problems. As these problems are identified, they will guide the direction of the research and development activity.

The Municipal Environmental Research Laboratory (MERL) in Cincinnati, Ohio, in cooperation with the U.S. Department of Agriculture, has improved our capability to compost sludge, a process that not only produces a useful material for conditioning soil but also substantially reduces the cost of processing sludge as well. The method utilizes simple aerobic microbiological techniques that reduce the organic matter in sludges to a stable, environmentally acceptable material. The process is now in use by cities as large as Washington, D.C., but is also well-suited to small communities. A manual is available to help engineers in designing compost systems.

The vertical tube reactor (VTR) system now undergoing pilot study uses an extended vertical U-tube (two concentric tubes) reactor to achieve optimum reaction pressures, temperature, and retention time for wet chemical oxidation. The tubes are suspended from the top of a conventional cased well and may extend to depths of over 5,000 feet. The waste fluid and air are injected into a tube at the earth's surface, and as they flow down the tube they undergo natural pressurization due to hydrostatic head. Thus, water pumps and air compressors need only be sized to overcome friction and gravity losses and do not need to develop the high pressures actually experienced at the bottom of the U-tube.

Treatment works operation and design. In its investigations into problems associated with the operation, maintenance, and design of wastewater treatment works, MERL has identified some 70 factors affecting the performance of such facilities.

Using their findings, the laboratory developed a composite correction program for evaluating problems at individual treatment works. If utilized effectively by permitting and enforcement authorities, this systematic approach could assist them in bringing into compliance as many as 70% of treatment works judged not to be meeting performance requirements.

Deficiencies in current POTW design are being addressed through a new design information series (DIS). These documents provide the most up-to-date design information and research results. In addition, a comprehensive two-volume design deficiencies matrix and corrective methodologies manual addresses over 3,000 deficiencies and recommends corrective action for both operation and design practices. New and improved operational procedures have been developed to minimize the impacts of in-plant sidestreams on plant performance. The results of extensive studies of the impact of peak hydraulic flows on plant performance are being reported as part of the DIS.

Land application and aquaculture techniques. Development work sponsored by the R. S. Kerr Environmental Research Laboratory in Ada, Oklahoma, has resulted in the construction of many treatment facilities across the country that utilize new or improved techniques for applying wastewater to the land. The most recent demonstration project is the large-scale land treatment system in Lubbock, Texas, where state-of-the-art design technology is being utilized on a new system along with modifications to the overloaded old irrigated system. The research has developed techniques that resulted in a 60% reduction in treatment facility construction cost over conventional costs and at least a 40% reduction in operating costs. Specific advantages of these techniques include reducing the problems of sludge disposal, reducing energy use, and making treated water available for beneficial purposes. In conjunction with the U.S. Army and the U.S. Department of Agriculture, EPA developed a design and construction aid, "Process Design Manual for Land Treatment of Municipal Wastewater," which is being widely used across the country. Land application technology will not be applicable to all locations since soil type, climate, land availability, and the character of the wastewater must be considered on a site-specific basis. It is, however, proving to be of particular value for solving small community problems.

Besides the manual, information is being developed on: nitrogen conversions as they affect the design and operation of rapid infiltration land application systems; overland flow design criteria for northern climatic zones; high-rate infiltration design and operating procedures for southern parts of the country; and pretreatment requirements for land application systems, including treatment achieved through storage. Since the bulk of the research associated with land treatment has been completed, this work will be substantially reduced beginning in FY 1982.

Investigations into the use of aquaculture techniques for treating and managing wastewater have also been initiated. Aquaculture research has in the past emphasized the development of biological/ecological systems—natural and man-made wetlands, vascular plants, invertebrates, finfish, shellfish, and various combinations of such systems—as polishing units following primary or secondary treatment. Current efforts also focus on aquaculture techniques as a means for providing basic treatment, thus replacing conventional techniques. The approach is twofold: Exploratory research identifies promising systems, and developmental research focuses on those systems that have the most potential for early utilization. Future developmental concentration is considered in terms of potential economic factors, resource recovery and reuse, product value, and energy conservation.

Urban runoff. Since 1966, research into problems associated with wet weather flows have indicated that this wastewater source can have significant detrimental effects on receiving waters. Concurrent developmental efforts have produced technology that can be applied to the control and treatment of surface runoff—both storm water and overflows from combined storm/sanitary sewers. These research products have enabled EPA to establish field programs for further assessment of storm water impacts, to develop management plans, and to control combined sewer overflows. These field programs are being carried out in conjunction with the Agency's national urban runoff program (NURP) to maximize EPA resources at select study locations such as Boston, Massachusetts, Lansing, Michigan, and Bellevue, Washington. The field work associated with these projects will be completed in FY 1981; interpretation, evaluation, and overall policy guidance development will be completed by FY 1982.

Current activities in the urban runoff program are numerous. They include development of technology for flow control and dual (wet/dry weather) treatment, preventive management techniques, effective management practices for municipal pollution abatement, and predictive and user assistance tools for implementing remedial actions. This research has produced criteria, guidelines, and methods for assessing and formulating solutions to urban-sewered and unsewered wet weather pollution. Recent publications include "Sewer System Evaluation, Rehabilitation and New Construction-A Manual of Practices." Future research will be guided by the Agency's construction grant strategy, now under development. Beginning in FY 1982, work in the urban runoff area will be substantially reduced. At this time it appears that research will be directed away from treatment and control technology for combined sewer overflows, but toward better means of evaluating and correcting infiltration-inflow (I/I) problems in the collection and transport system.

Small wastewater flows. Several major difficulties have arisen with respect to implementation of alternative technologies in small communities. Low-cost comprehensive facility planning techniques are needed; planners need improved applicability, cost, and performance data bases in order to assess alternative technologies; understanding of the public health and environmental impacts of these technologies is still limited; and long-standing attitudes of public officials, engineers, and the general populace toward appropriate technologies for small communities must be changed.

Research efforts have concentrated on low-cost collection systems, alternative on-site wastewater treatment and disposal systems, and alternative methods for handling residuals from on-site systems. In addition to developing design, construction, operation and maintenance, and management techniques, the program is being broadened to encompass improved facility planning methodology, public health impacts, and anticipatory studies of utility systems that may be integrated into advanced building technologies. Early work produced a definitive report, "Management of Small Waste Flows," which is the underpinning of EPA's effort to utilize on-site and cluster systems for small populations in lieu of conventional sewers and treatment facilities. "Design Manual—On-site Wastewater Treatment and Disposal Systems" offers small communities a lower-cost wastewater management option for design and construction of such facilities.

Innovative and alternative technology. The innovative and alternative (I/A) technical support group at MERL in Cincinnati, Ohio and at Ada, Oklahoma was established to assist in the administration of the innovative and alternative requirements of the construction grants program. To qualify for an I/A construction grant, an applicant must demonstrate tangible benefits—the savings of life cycle costs and energy—and intangible benefits—improvement of operational reliability, toxics management, environmental quality, and industrial-municipal joint treatment potential.

In 1980, EPA initiated a new active I/A technology program to provide direct technical and administrative assistance to municipalities developing I/A projects at the local level. The highly trained, experienced professionals in the technical support group arrange and conduct workshops dealing with both technical and administrative aspects of the I/A program and consult with staff agency personnel, engineers, and local officials. As part of the program's effort, a number of emerging technology assessment reports are being completed and distributed in order to disseminate information on recent advances in wastewater treatment. Twenty-five such assessment documents are planned.

Health effects. Health effects research activities are concentrated primarily in three areas: wastewater and sludge management, reuse and recycling of wastewater, and urban runoff. Studies are progressing on the health effects associated with technologies for wastewater and sludge management and on the potential for groundwater contamination. Of particular concern in the latter area are the effects that could result from human exposure to varying concentrations of microorganisms, organics, pesticides, and specific metals in municipal sludge. Long-term health effects studies are being carried out on populations near the Lubbock, Texas, land treatment project and on farm families, which use garden products grown on soils treated with sludge. Recent efforts in urban runoff research include evaluation of the need for advanced wastewater treatment to obtain a virus-free effluent to prevent adverse health effects in recreational waters, and development of better indicators of microbiological treatment efficiency.

Monitoring systems and quality assurance. The monitoring systems activities are designed to support the Regional and Program Offices in environmental impact statement preparation, septic tank problem analysis, and implementation of the Enviro-pod Program. Enviro-pod is a two-camera system mounted on standard aircraft and is available to the Regional Offices to support program needs. In addition to meeting requests for overhead monitoring data, technical support is provided on a continuing basis to the Regional Offices and the emergency operations of the oil and special materials control program to help solve environmental problems.

EMERGING PROBLEMS AND ASSOCIATED RESEARCH NEEDS

In 1980, an intra-agency committee was established to assist the Office of Research and Development in identifying research requirements and planning the needed research. The Municipal Wastewater and Spill Prevention Research Committee identified several developing trends in the municipal area that it believes will grow in importance. If sustained over time, these trends will require not only planning and implementation for research activities, but planning and implementation for remedial action programs as well.

The rapidly accelerating cost and decreasing availability of energy sources will continue, necessitating drastic changes in conventional approaches to wastewater management. These changes must include conservation of energy in the facilities, production of energy through biomass technology or other means, automation and other techniques for optimizing plant efficiencies, and use of solar and wind energy.

As the cost of land for treatment works continues to rise and as available sites diminish, technology and design techniques to permit more efficient use of land will be necessary. Such techniques will be particularly important in the area of sludge management. Current research is attempting to expand options that are both energy conscious and environmentally sound. For example, ORD expects by 1990 to demonstrate technology that reduces the volume of sludge for disposal while recovering energy (anaerobic digestion with methane recovery), as well as processes for the thermal destruction of sludge (high-efficiency incineration) with heat recovery.

Operating difficulties and costs associated with conventional systems will gradually result in a movement toward the use of land treatment and aquaculture systems, especially in smaller communities. These systems can produce high-quality effluents or, with some techniques, no surface or point discharge at all. They offer the advantage of little or no sludge production, are low energy users, and can produce biomass for beneficial purposes. Operation can be quite simple compared to conventional systems.

Public attitudes, available technology, and cost and financing conditions relating to wastewater control are all changing at a rapid pace. The effects of new technological approaches to wastewater management have become visible within the past five years, some of which are already having an impact on the selection of treatment systems on local levels. A relatively new land treatment method called "overland flow"—a system that allows wastewater to flow over the land surface in a thin sheet, with grasses and other vegetation providing the environment needed for the microorganisms to grow and utilize the nutrient materials in the wastewater for growth—is gaining rapid acceptance. While there are only a few small "first generation" overland flow facilities in the United States, they are frequently being proposed as part of the Agency's innovative/alternative construction program. Unlike other land treatment methods, overland flow has a discharge of treated wastewater, producing at low cost an effluent quality equivalent to conventional secondary treatment. The Easley, South Carolina, overland flow project is one such project being supported and monitored by EPA. The R.S. Kerr Laboratory was instrumental in the development of this system and is continuing to study and evaluate it. Data from this and similar projects will be used to improve future applications of the technology and for inclusion into the updated version of the process design manual referred to earlier.

Another "natural" system considered to have considerable potential for widespread use is now being pilot tested. Similar to overland flow in some respects, the nutrient film technique is a modified hydroponic system. A nutrient solution (or wastewater) is discharged in a thin film over a non-porous membrane that is overlaid with aquatic plants and/or non-aquatic vascular plants. Plants being studied as possible biomass prospects for these systems include several grasses, cattails, bullrushes, and similar water-tolerant species. Very promising results to date have been obtained principally by Cornell University, which has received financial support from EPA, Department of Energy, and Department of the Interior. If current experimental work continues to succeed, these systems will be widely adopted because of several advantages: They use little energy, require low levels of maintenance, produce useful by-products, and can withstand cold climates.

The use of small-flow systems has greatly expanded in the last three or four years. The Small Flows Clearinghouse at West Virginia University, financially supported by an EPA cooperative agreement, has stimulated so much interest in the available technologies that EPA is considering expansion of the clearinghouse service to include information on small drinking water systems. MERL plans to establish a Small Community Wastewater Treatment Center during 1981; the center will not be located in a single physical site, but will utilize local facilities and treatment programs in the greater Cincinnati area to conduct practical on-site research and evaluation of small-system technologies.

A further MERL plan is to utilize the newly established test and evaluation facility to evaluate new treatment systems expected to be the forerunners of new directions in wastewater management; several anaerobic treatment configurations will be evaluated in 1981. The facility also will be utilized to study toxic materials in municipal wastewater. Utilizing small-scale treatment works, studies will be undertaken to improve understanding of the fate of materials in the treatment works and to develop better techniques and technology for controlling or removing them.

As energy considerations continue to grow in wastewater management, EPA's research and development activities will become more closely coordinated with similar programs in other agencies. Of particular importance is the Department of Energy's new effort directed toward energy conservation and production at waste treatment facilities. For several years, DOE and EPA have cooperated in this program area, but expanded DOE resources now offer the opportunity to make more rapid progress.

Transferring technology from research and development to the public user is a difficult task. The risks inherent in field trials of new technologies deter their rapid adoption by the engineering community, state agencies, and municipalities. Nonetheless, the Clean Water Act's establishment of the innovative and alternative technology program provides an administrative push toward utilizing the latest technologies. Movement in that direction over the past two years, however, has made little significant change in the character of publicly owned treatment works.

The newly established active innovative/alternative technology program is working to actively promote the use of the latest technologies. A recent report prepared by MERL's technical support group, "Impacts of National Innovative and Alternative Technology Programs and Justification for Extension into Fiscal Year 1982," illustrates the value of this kind of program. For example, a $21 million expenditure of FY 1979 construction grant funds is estimated to save $133 million due to adoption of innovative technology. This figure is equivalent to a 633% return for each dollar set aside in the I/A program. A $63 million expenditure of FY 1979 alternative set-aside funds is expected to save a total of $365 million because of alternative technology use. This amount is equivalent to a 579% return for each alternative set-aside dollar spent.

These early results of promoting the use of more appropriate technology, coupled with the need for widespread improvement in treatment works costs and efficiencies, indicate that more work on promotional efforts is needed. The next few years are likely to see a greatly upgraded and visible effort by EPA's research and construction programs to promote the use of more up-to-date, cost-effective technologies. The research and development program will play a dual role in this effort: It will continue to improve wastewater management capabilities through research and development and will provide a great deal of the expertise the agency needs to mount an aggressive and successful technology marketing effort.

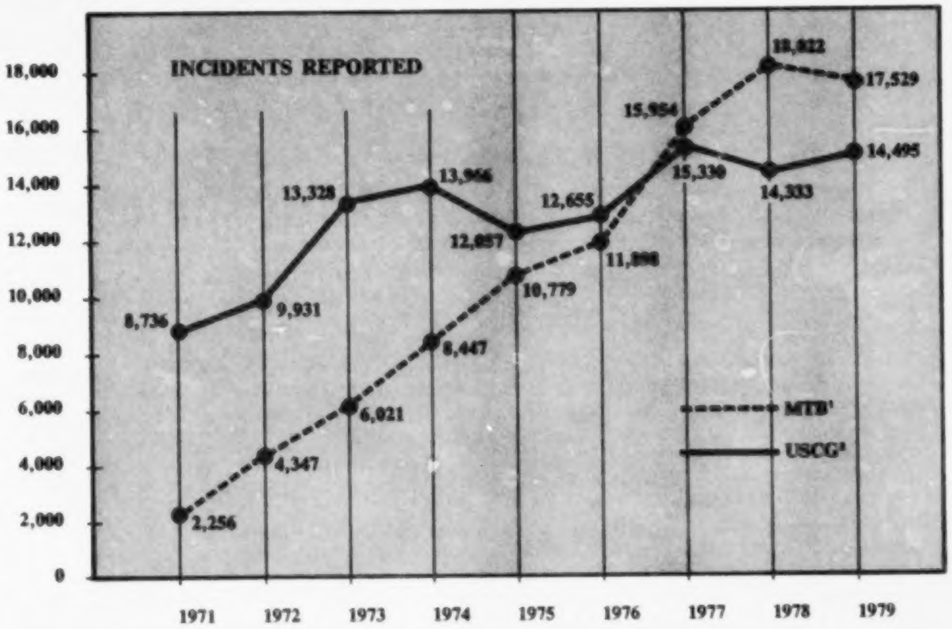
EMERGENCY SPILLS RESEARCH

By virtue of their high visibility and frequently catastrophic effects, hazardous substance spills are currently receiving attention at all levels of government as well as in the private sector. The problem of spills is an enormous one. While their number is difficult to assess since many go unreported, it is, in any event, estimated that the figure significantly exceeds the 15,000 spills annually reported in the U.S. In response, vast sums of money and manpower are expended throughout government and industry today in an effort to prevent spills and, when they occur, to minimize environmental degradation.

A spill generally contaminates the air, land, and water, rapidly spreading and dispersing into the atmosphere, soil, and surface or groundwater. As a consequence, the problems they pose are extremely diverse, involving a multidimensional matrix of spilled substances, volume spilled, location and condition of the spill site, weather, and a host of other influencing factors.

Spills may consist of toxic, infectious, corrosive, flammable, or explosive substances; and waste products such as dredge spoils, solid waste, sewage, and off-specification chemicals. These agents can be released from waterborne vessels, land vehicles, pipelines, and production, storage, and transfer facilities; at fault can be structural failures, equipment malfunctions, collisions, human errors, or, in some instances, deliberate acts. In the face of such manifold sources and culprits, significant progress has been

OIL AND HAZARDOUS MATERIALS INCIDENTS 1971 - 1979



[1] Materials Transportation Bureau. Does not include bulk shipment by marine mode; includes oil only where regulated as a hazardous material. Source: U.S. Department of Transportation, 1980. Tenth Annual Report of the Secretary of Transportation on Hazardous Materials Control.

[2] U.S. Coast Guard. Includes only spills into U.S. waters. Source: U.S. Coast Guard, 1980. Polluting Substances In and Around U.S. Waters, COMDTINST M16450.2B.

made in the development and application of technology for spill prevention and control. There is still, however, the need to continue and accelerate such research, to advance the state of the art.

Slightly more than a decade elapsed between the oil well blowout in California's Santa Barbara Channel that first focused widespread public attention on the oil spill problem, and the 1979 blowout of Ixtoc I in Mexico's Bay of Campeche, which resulted in the worst oil spill in modern history. This same ten-year period has seen establishment of the EPA and its Spills Research and Development program, a program that has responded to the needs of Agency and other government offices as well as industry; providing, where possible, solutions to challenging spill problems. Changing national priorities, as expressed in the legislation of the decade, have set the tone for this effort, beginning in 1969 when the National Environmental Policy Act set the stage for the formation of an agency to protect the environment. This was followed by the Federal Water Pollution Control Act of 1972 which required the reporting and cleanup of spills. The Clean Water Act of 1978 then amended the requirements for spills reporting and cleanup, making them more stringent. Today, "Superfund" legislation may expand the applicability of spills response action to land areas as well as U.S. waters.

Research and development program accomplishments are evidenced by the number of new technologies that have been developed for use in the event of spills and in support of EPA spill regulations.

In addition to making use of the technology developed by the research and development program, spill response personnel can today request technical assistance from the program's Environmental Emergency Response Unit (EERU) in Edison, New Jersey, and the Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). The EERU is a model testing ground for complex spill cleanup equipment and techniques. At EERU, spills response and control equipment developed by contractors is delivered for shakedown, evaluation, and

SPILL TECHNOLOGY DEVELOPED BY ORD

Commercially Available

- Mobile physical/chemical treatment system using granular activated carbon (built by O.H. Materials, Inc., Findlay, OH)
- Cyclic colorimeter for detection of heavy metals in water (marketed by Calspan Corp., Buffalo, NY)
- Hazardous materials detection kit to detect and monitor the location of chemical spills in water when the identity of the chemical is known (marketed by Hach Co., Ames, IA)
- Organo-phosphate pesticide detection and warning system (manufactured by Midwest Research Institute, Kansas City, MO)
- Foam dike system which provides an "instant dike" from a portable backpack apparatus for the emergency containment of spilled hazardous substances (marketed by MSA Research Corp., Evans City, PA)
- Acoustic emission earth dam spill alert device, a passive device for determining the stability of earthen dams containing hazardous chemicals (supplied by two U.S. firms and a British firm)
- Dynamic inclined plane skimming system — a vessel for removing spilled oil from choppy harbor waters at 2 knot currents (marketed by J.B.F. Scientific Corp., Wilmington, MA)

Field-Tested Prototype

- Mobile Chemical Laboratory — consisting of a sophisticated complement of instruments (GC, IR, AA, etc.) for performing analyses at oil spills and chemical emergency situations in remote field locations
- Spill Assessment Laboratory — consisting of a self-propelled laboratory, equipped to perform in-field treatability studies for cleanup of hazardous material spills and industrial dumpsites
- Safety/Decontamination/Office Trailer — a mobile field office and safety station to provide office space for the EPA On-Scene Coordinator at a cleanup, a storage location for safety and communications equipment, and emergency shower for spill site personnel
- Mobile Stream Diversion System — a trailer-mounted pumping and piping system for the diversion (up to 3000 feet) of small (up to 12.5 CFS) streams that have been contaminated by spills for the purpose of isolating the contaminated segment of the stream to facilitate cleanup operations
- Mobile Froth Flotation System — a trailer-mounted froth flotation system to clean oil-contaminated beach sand
- Pump/Collection Bag System — a pallet-mounted emergency collection bag and pumping system, consisting of a 7000-gallon furled teflon-coated urethane bag and battery-powered or explosion-proof gasoline motor-driven pumps, for temporarily storing spilled hazardous chemicals
- Gelling Agent System — a trailer-mounted multi-purpose gelling-agent system for solidifying and immobilizing spilled hazardous liquids and preventing their penetration through the soil into groundwater supplies
- Spill Alarm System — an in-stream warning system consisting of a number of individual probes and sensors (TOC, conductivity, UV absorption, etc.) for the continuous detection of a broad variety of spilled hazardous materials in water
- Enviro-pod Aerial Monitoring and Surveillance — a compact reconnaissance system designed to be secured to a widely available aircraft to provide vertical and forward-looking photographic images to high resolution
- Water Jet Boom System — a system capable of moving spilled oil horizontally relative to the water it floats on (even in the presence of waves) for either diverting the oil in high water currents or increasing the effective encounter width of skimming equipment
- Oil Dispersant Application System — a system of port and starboard spray booms and associated pumps, hoses, and fittings, designed to be installed on a vessel for the application of oil-dispersing chemicals to an oil spill at a rate of 268 acres per day
- Mobile Decontamination Station — a semitrailer van designed to support the personnel decontamination needs of cleanup activities involving highly toxic materials

Prototype Undergoing Operational Testing

- Powdered Activated Carbon System — a mobile physical/chemical treatment system designed to use powdered carbon, and including provision for flash mixing with chemical addition, flocculation, settling (with sludge dewatering), mixed-media filtration, and associated support equipment
- Mobile Carbon Regenerator — a mobile carbon reactivator system, designed for field use in reactivating carbons used on environmentally sensitive compounds such as Kepone, dioxin, or PCBs which cannot be either transported or commercially reactivated; system consists of kiln, fume incinerator, quench section, and scrubber section
- Mobile Soils Grouting/Detoxification System — a soil treatment system designed to inject grout, chemicals, or microbiological materials into soils for the purpose of reducing groundwater movement or in-place washing or detoxification of soils that have become contaminated with spilled hazardous materials or leachates from uncontrolled industrial waste sites

Under Development

- Mobile Incinerator — a system consisting of three semitrailers equipped with a rotary kiln, an afterburner and an air pollution control train for the incineration of toxic organic compounds
- Mobile Soils Washing System — a soils cleaning system designed to separate spilled PCBs or other compounds from soils on-site

demonstration under actual field conditions. In addition, the EERU also serves as a spills information source and provides technical assistance in cleanup or control situations.

The EMSL-LV provides remote sensing support to the on-site spill coordinators on a request basis. Through the use of contractor aircraft or the Enviropod program the laboratory provides aerial photography and analyses within a 6- to 24-hour period after notification. The EMSL-LV also operates the Agency program for using aerial photography to analyze petroleum storage and transfer facilities.

The program acquires imagery of selected sites, performs analyses and provides the data to regional compliance monitoring teams prior to their scheduled on-site inspections.

Current Problems and the Research and Development Program

The spills research program develops, evaluates, and demonstrates new or improved equipment, systems, and techniques to prevent, detect, identify, contain, control, remove, clean up, or recover spills or acute releases of oil and hazardous polluting substances. The program's objective is to accomplish those tasks while at the same time assuring that every precaution is taken to protect the water, land, and air from accidental releases, and that cleanup operations employ only the most environmentally sound methods. The hardware and techniques developed under the program are carried beyond the prototype stage to the point where they are ready for field implementation by the commercial community.

Currently, the program's long-standing emphasis on cleanup equipment is being augmented by a new emphasis on spill personnel safety and the search for a better understanding of the interaction between spills and the environment. Among the questions being addressed are:

- "How clean is clean?" Given the assimilative capacity of the environment and economic considerations, response officials require a mechanism to determine when a spill is sufficiently "cleaned up."
- "How can biologically damaged ecosystems be repaired, and how long does the repair take?" Techniques must be developed to reverse and mitigate damaging spill effects in a timely manner.
- "What are the fate and effects of spilled materials?" A scientific determination of cleanliness must be made, rather than one based on engineering judgment.
- "What initial actions are to be taken at a spill site?" Firemen and other first-on-scene non-technical response personnel must know the proper emergency actions to be taken.
- "Can light aircraft and television systems provide the on-site coordinator with valuable real-time information on spill cleanup?"
- "Can automated data processing techniques be used to improve cleanup decision-making?" There is a need for the prompt application of knowledge from previous spills to present spill responses.

These questions provide the basis for many of ORD's hazardous substances spill research projects, either already under way or scheduled for the near term.

Specifically, in the area of information transfer and prevention, ORD is performing research and development to:

- determine the causes of past spills;
- determine the feasibility and cost effectiveness of spill prevention through risk analysis and the development of health hazard criteria;
- develop spill prevention techniques and equipment; and
- provide aggressive, credible information transfer through shakedown and demonstration of field usable research and development techniques and equipment.

The development of effective initial responses to spills and their subsequent management is addressed in the area of pre-spill response planning, safety, and assessment. The research and development effort includes:

- pre-spill response planning;
- protection of response personnel;
- spill identification and detection; and
- impact prediction for air, surface water, groundwater, and land.

The objectives of the spill containment and confinement, and spill separation and concentration program are to develop techniques to limit spreading of a spill and to separate spilled material from air, water, soil, and sediments that have been affected. Research in this area includes:

- developing and demonstrating containment and confinement equipment and techniques;
- developing and demonstrating techniques for the on-site separation of spill materials from treatment agents and impacted environmental media;

- developing and demonstrating techniques to concentrate dispersed spilled materials;
- developing and demonstrating techniques for the control of volatile substances; and
- providing technical support for field use of spill control techniques.

The ultimate disposal program is currently of particular interest to the Agency, both because of the severe hazards posed by recovered residues and in light of the increased regulation of hazardous waste under the Resource Conservation and Recovery Act of 1976 (RCRA). Research and development in this area includes:

- assessment of various ultimate disposal alternatives; and
- development or adaptation of on-site disposal techniques for non-reusable contaminated waste and debris, emphasizing on-site disposal.

The object of the fate and effects program is to determine the immediate and long-term damage to the environment that results from acute discharges of hazardous substances. Study in this area focuses on natural processes and at what point they can no longer cope with spilled material, and when spills present short- or long-term hazards that must be addressed.

The restoration of the environment research and development program looks to accelerated natural restoration as both a complement to, and a substitute for, active spill control and removal operations that make use of mechanical equipment. The program is designed to:

- evaluate currently available restoration practices;
- develop techniques and equipment for accelerating recovery; and
- develop techniques and equipment for rapid determination of the level of restoration required.

Clearly, the most effective means for protecting the environment from oil spills is to prevent them altogether. Providing scientific support for the regulatory activities in spill prevention, control, and countermeasure (SPCC) is ORD's oil spill prevention research program, which evaluates present SPCC regulations and provides technical support for revisions. Near-term projects of the program include:

- an evaluation of the effectiveness of the present oil spill prevention regulations in reducing spills;
- development of a guide for improved spill prevention systems and practices; and
- continued aerial surveillance for SPCC monitoring and enforcement.

Under the oil spill control and cleanup program, EPA works jointly with the U.S. Coast Guard, Navy, Geological Survey, and other agencies to assess, develop, and demonstrate the effectiveness and capabilities of equipment and techniques to control and clean up spills of oil on land and water. Ongoing ORD support to EPA's Office of Water and Waste Management includes:

- operation of the Oil and Hazardous Materials Simulated Environmental Test Tank facility (OHMSETT);
- development of a television "real-time" data transfer to the on-scene coordinator;
- development of new analysis techniques with aerial photography and multi-spectral imagery;
- development of environmentally acceptable guidelines and techniques for cleanup operations;
- development of guidelines and techniques for the protection and restoration of shorelines damaged by oil spills; and
- provision of technical support for spill control and removal.

Emerging Problems and Research Requirements

A key responsibility of the ORD spill research and development program involves the timely and effective transfer of information on newly developed equipment and techniques for effective spill cleanup from the research community to the user community. As the number of private groups and federal and state agencies performing research expands, and as the user community grows more numerous and diverse, this is a task that becomes more challenging each year. To augment this effort, ORD, in conjunction with the Office of Water and Waste Management (OWWM), cosponsors annual national spill conferences, as well as operating its Emergency Environmental Response Unit (EERU) to assist in the transfer of state-of-the-art information to all potential users.

Another major ORD concern is the support of pre-spill planning at local and regional levels. Such planning could save valuable response time and significantly reduce spill impacts by reducing the areal extent of the spill, while at the same time protecting the lives of the public and response personnel. Effective spill contingency planning by states and municipalities requires the development of spills response guidance manuals as well as the refinement of automated data processing assisted techniques to aid in spill control decision-making. With access to these tools, local and regional agencies could evaluate a number of control options in the limited amount of time available for spill response. This, in turn, would increase the likelihood that the steps taken would be the most effective cleanup methods for that specific situation.

Of ongoing importance is the continuing development, evaluation, and improvement of spill control and cleanup equipment and techniques. Research and development efforts are required in the following problem areas:

- specifications for equipment and procedures to protect spill response personnel, to include decontamination procedures for personnel and equipment;
- development of effective spill control decision-making procedures for
  - essential sampling and analysis
  - choosing alternative cleanup and disposal options
  - establishing quality assurance procedures;
- development of procedures to contain and confine spills and limit their spread;
- development of procedures to concentrate and separate spilled materials from co-collected air, water, soils, and sediments;
- development of procedures for on-site destruction or other ultimate disposal of collected, concentrated spilled materials;
- development of advanced techniques for accelerating the natural processes of assimilation of spilled materials into the environment and restoring impacted areas to their pre-spill condition; and
- continuation of remote sensing techniques and support for compliance monitoring.

These problem areas are currently being addressed by ORD at its Edison, New Jersey facility and at the Environmental Monitoring and Support Laboratory in Las Vegas, Nevada. Exact timetables will depend on the availability of resources, and work may either be accelerated or delayed as appropriate. Of note, passage of "Superfund" legislation will greatly expand the role played by EPA in the handling of problems associated with hazardous materials spills and uncontrolled hazardous waste sites, and would, in turn, require an expanded supportive research and development effort. While much of the technology now flowing from research and development activities associated with hazardous materials spills will have utility in or be transferable to the solution of problems developing from uncontrolled hazardous waste sites, "Superfund" legislation will also require extensive field investigations, quality assurance, and remedial action to be taken at hundreds of hazardous waste sites. The safety of field personnel and the availability of effective hazardous materials control, containment, and disposal procedures will all depend, to a large extent, on an research and development program suitably designed to meet the challenges posed by these tasks.

Future Trends

Future trends in oil and hazardous substances spills research will be influenced by:

- an expected increase in the number of spills;
- the projected decrease in the availability of disposal sites;
- the possible requirement that affected areas be returned to pre-spill conditions;
- an increased emphasis on the use of dispersant technology offshore; and
- the use of genetic research to provide cleanup agents.

Increased number of spills. An annual increase is projected for the number of reported transportation- and non-transportation-related spills. Some of this increase will be due to new, more stringent reporting requirements, but other expected increases will be affected by:

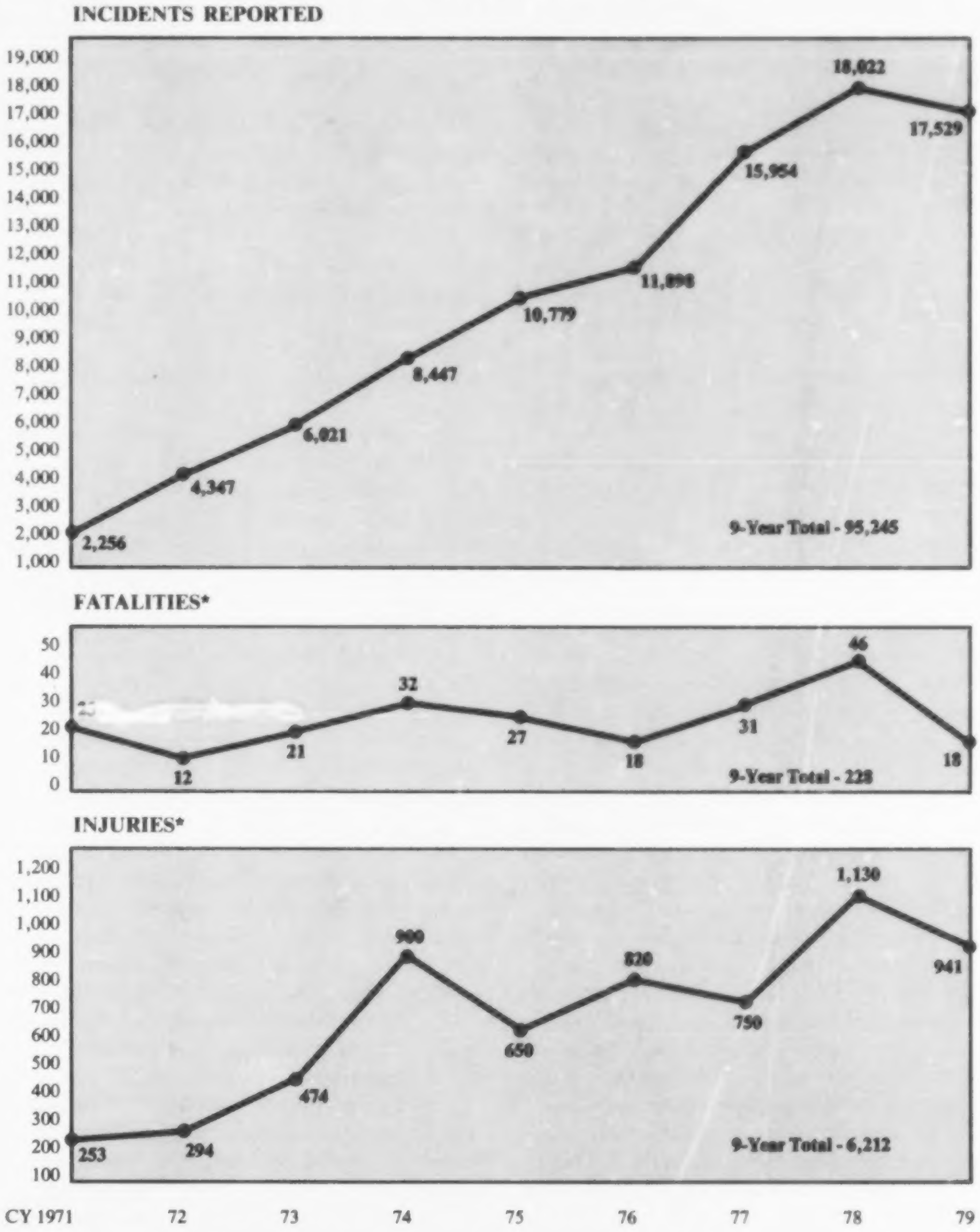
- increased manufacture of hazardous materials;
- increased transportation of hazardous materials;
- increased transportation of hazardous residues as a result of cleanup operations; and
- increased storage/treatment/disposal of hazardous waste due to RCRA regulations.

By illustration, annual hazardous waste generation is expected to nearly double by the year 2000. In addition, hundreds of new chemicals, many of which are hazardous, are being developed and entered into commercial use annually. Such expanded production and use invariably entails increased transportation and handling, with subsequent increases in spill opportunities; transport volume is on the upswing and distances transported are greater. Yet another factor increasing the potential for future spills is the deterioration of the transportation systems themselves—rails, roadways, pipelines, and vessels.

Data gathered from 1971 through 1979 indicate that oil and hazardous materials incidents, fatalities, and injuries are large spill problems now and ones that are on the rise.

Decreased availability of disposal facilities. One of the short-term effects of the recent RCRA regulations has been a decrease in the number of facilities available for disposal of hazardous residues from spill cleanup operations. Also contributing to what is expected to

HAZARDOUS MATERIALS INCIDENTS, FATALITIES, AND INJURIES: 1971-1979



*** Directly Attributable to Unintentional Release of Hazardous Materials**

Source: Tenth Annual Report of the Secretary of Transportation on Hazardous Materials Control, U.S. Department of Transportation, 1980.

be a continued shortage is public opposition to the siting of new disposal facilities. As a consequence, ORD is currently emphasizing the development of on-site disposal technology, focusing on mobile equipment that can be rapidly transported to a spill site to dispose of spill materials, then moved to another for reuse. Such mobile on-site disposal is cost effective, while reducing the likelihood of a secondary spill during the transport of spill residues.

Two such disposal systems are currently under development at ORD: a mobile carbon treatment system and a mobile incinerator. In addition, a joint effort with the Maritime Administration is evaluating the feasibility of at-sea incineration as a disposal option. Results of these and other research projects will provide the on-scene decision maker with a variety of cost-effective options for the disposal of recovered spill residues.

Complementing spill research and development will be the research taking place in the Solid and Hazardous Waste Research Program which is also involved in improving treatment and disposal technology, though not specifically related to the spill problem.

Return to pre-spill condition. Future trends in environmental regulation may lead to a requirement that spill sites be restored to their pre-spill condition. Such restoration efforts will, if required, relate closely with research to determine "How clean is clean?", already underway at ORD. On-scene decision makers will have to be able to determine when adequate cleanup has been accomplished. Currently, this decision is made based on the best engineering judgment of the spill cleanup coordinator, a judgment that weighs the costs of further pollutant removal against the benefits. A requirement to return the spill site to its pre-spill condition, however, would mean that cleanup operations would not be terminated until whatever remains of a spill can be naturally assimilated by the environment. To ensure that the decision to terminate cleanup will be made on a sound scientific basis, extensive study into the environmental fate and effects of spilled hazardous materials will have to be undertaken.

Dispersant technology. In spite of over ten years of oil spill prevention, control, and removal research and development, no truly effective offshore oil containment/removal methodology has been found. The

OIL AND HAZARDOUS MATERIAL INCIDENTS REPORTED 1980

Mode	MTB[1]	USCG[2]
Air Carriers	289	—
Highway Carriers (for hire)	15,355	—
Highway Carriers (private)	623	430
Rail Carriers	1,215	65
Other Land Carriers	—	84
Water Carriers	34	4,417
Freight Forwarders	2	—
Pipeline	—	472
Facilities	—	3,347
Unknown	11	5,680
Total	17,529	14,495

[1] Materials Transportation Bureau. Does not include bulk shipment by marine mode; includes oil only where regulated as a hazardous material. Source: U.S. Department of Transportation, 1980. Tenth Annual Report of the Secretary of Transportation on Hazardous Materials Control.

[2] U.S. Coast Guard. Includes only spills into U.S. waters. Source: U.S. Coast Guard, 1980. Polluting Substances In and Around U.S. Waters, COMDTINST M16450.2B.

recent development of nontoxic dispersants for use on offshore spills, however, may signal a change in this trend. These dispersants may be applied to spills where they occur, thereby protecting the highly vulnerable ecosystems found in coastal areas where investigations have revealed that most of the long-term damage from spills is manifest. This damage, along with offshore spill effects, could, it is thought, be largely averted through the development and use of environmentally compatible dispersants. Future research and development will continue to study the potential for these dispersants as well as the effects of oil on the offshore environment.

Genetic research. The potential of genetic engineering to develop special-purpose microorganisms for the biological control of oil and hazardous substance spills is still to be fully realized. A recent court decision upholding the patentability of these microbes, however, indicates that perhaps another powerful tool may sometime be available for spill cleanup. It is possible, for example, that in the future, banks of specially engineered microbes will be maintained in populations suitable for immediate dispatch to a spill site. Support will be provided in 1981 to explore the feasibility of pursuing the application of this technology to the mitigation of spills of hazardous materials.

MUNICIPAL WASTEWATER RESEARCH PLAN

Wastewater Process Development

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
New or Improved Biological Process Development	Upgrade lagoon treatment by simple low-cost methods	▲				
	Develop efficient method of O_2 transfer to biological systems		▲			
	Study rotating biological contactor (RBC) systems		▲			
	Evaluate batch reactors and fluidized bed reactors			▲		
Biodegradation and Specific Pollutant Removal	Perform biodegradation studies of priority pollutants	▲				
	Study nutrient removal	△		▲		
Microbiological Control	Study ozonation			▲		
	Study ultraviolet light (UV)			▲		
	Study disinfection of antibiotic-resistant organisms		▲			
	Study disinfection state-of-art technology transfer	△		△		
Wastewater Reuse and Water Conservation	Demonstrate potable water reuse in Denver			(construction complete) △		(FY 88) ▲
	Demonstrate potable reuse at existing sites			▲		
	Examine water conservation practices impact on wastewater collection and treatment systems		▲			
	Develop non-potable reuse criteria and system evaluations			▲		

MUNICIPAL WASTEWATER RESEARCH PLAN

Toxic Pollutants Control

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Toxic Pollutants Control	Develop and manage toxics database, including information on alternative indicators	▲	▲	▲	▲	
	Evaluate and develop toxics removal processes		△	△	▲	
	Develop data on toxics treatability	▲			▲	

MUNICIPAL WASTEWATER RESEARCH PLAN

Plant Operation and Design

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Plant Operation and Design	Assess poor efficiency and reliability	▲				
	Conduct sensitivity and system analysis of factors affecting reliability, cost efficiency, and energy effectiveness			▲		
	Conduct supporting technical studies to achieve improvements in cost, energy efficiency, and reliability		▲			
	Assess process control, instrumentation, and automation	▲	▲	▲	▲	
	Conduct urban assessment and system analysis				▲	
	Demonstrate composite correction program in Colorado and in a second location to be chosen		▲		△	

MUNICIPAL WASTEWATER RESEARCH PLAN

Sludge Management

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Processing and Stabilization	Conduct study on dewatering and conditioning	▲				
	Evaluate disinfection and stabilization techniques	▲				
	Develop energy-saving sludge technologies	▲				
	Investigate toxicant removal approaches	—	—	—	—	▲ (FY 86)
Conversion and Energy Recovery	Evaluate thermal processes and energy recovery	—	—	—	—	▲
	Perform complete characterization of sludge incineration emissions	—	—	—	—	▲
	Evaluate composting and other conversion processes	—	▲ (bi-year)	▲		
	Study emerging resource recovery processes	—	▲	▲		
Land Application Management and Disposal	Assess impacts of toxicants on crop response and site life	—	▲	▲		
	Evaluate sludge management practices for soil systems	▲	—	▲		
	Assess fate and effects of pathogenic organisms	▲	▲	▲		
	Assess use of sludge for energy and other non-food-chain crops	—	▲	▲		
	Assess long-term impact of high rate application on soil	▲	▲	▲	▲	

MUNICIPAL WASTEWATER RESEARCH PLAN

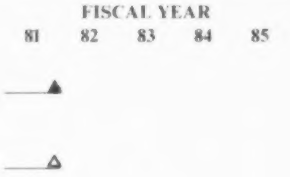
Land Application of Wastewater and Aquaculture

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Land Application of Wastewater	Complete review of systems by land treatment task force	▲				
	Assess long-term effects from six slow-rate systems	▲				
	Develop mathematical model for determining kinetics and reactions of phosphorus in soils					
	Publish land treatment design manual	▲				
Aquaculture and Use of Other Natural Systems	Evaluate use of fish species in wastewater treatment	▲				
	Evaluate effectiveness of water hyacinths for treating primary and secondary effluents	—	▲			
	Evaluate artificial and natural wetlands for treatment and disposal	△	△	△	▲	
	Transfer developed information and technology	—	—	—	—	■

MUNICIPAL WASTEWATER RESEARCH PLAN

Urban Runoff

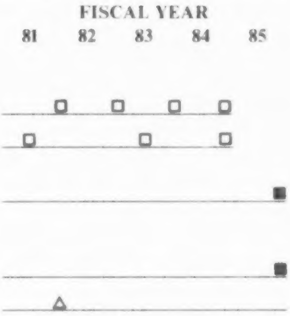
PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES
Urban Runoff	Carry out stormwater pollution problem assessment
	Develop controls and corrective measures (including expanded infiltration/inflow control program) for combined sewer overflow pollution



MUNICIPAL WASTEWATER RESEARCH PLAN

Small Wastewater Flows

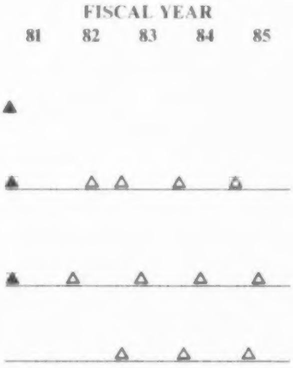
PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES
Small Wastewater Flows	Develop systems management approach for small communities
	Develop alternative technology for small systems
	Establish and maintain Small Flows Clearinghouse, West Virginia University (continuing function)
	Establish and maintain research activity at Small Flows Study Center (Cincinnati) (continuing function)
	Public Health Impacts Symposium (Oklahoma)



MUNICIPAL WASTEWATER RESEARCH PLAN

Innovative and Alternative (I/A) Technology

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES
Innovative and Alternative (I/A) Technology	Evaluate whether I/A program is meeting national goals for FY 1979 and 1981
	Provide assistance to regions through I/A technology clearinghouse in MERL, Cincinnati as part of national I/A effort (continuing function)
	Provide guidance and support to state and Regional Offices in evaluating I/A applications in construction grants program through I/A technical support group at MERL (continuing function)
	Evaluate I/A technology projects built by construction grants program (evaluation reports for selected facilities)



MUNICIPAL WASTEWATER RESEARCH PLAN

Health Effects

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Health Effects	Study land application of sludge and treated wastewater		▲ ▲	▲		
	Assess health effects associated with domestic wastewater reuse		▲		▲	
	Appraise health effects of other sludge treatment, disposal, and utilization practices			▲	▲	

MUNICIPAL WASTEWATER RESEARCH PLAN

Monitoring Systems and Quality Assurance

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Systems and Quality Assurance	Report on multi-spectral scanner operation	▲				
	Provide enviro-pod support to regional real-time TV system	▲				
	Report on use of aerial imagery to analyze septic tank problems		▲			
	Assist Ocean Discharge Program (as required)	□				
	Provide support for construction grants, Office of Environmental Review, and Regions in preparation of environmental impact studies and septic tank analysis (as required)	□				

MUNICIPAL WASTEWATER RESEARCH PLAN

Hazardous Substances Spills

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Information Transfer and Prevention	Perform statistical analysis of spills (frequency, cause, volume, cleanup cost)	▲				
	Develop/demonstrate fail-safe devices (level gauge, transfer line)		●			
	Perform risk analysis of chemical manufacturing, transportation, and waste disposal industries		▲			
	Develop spill prevention techniques and equipment				●	
	Develop background for guidelines on the prevention and control of pesticide spills	▲				
	Shakedown and demonstrate new techniques at spill sites		■		■	■

MUNICIPAL WASTEWATER RESEARCH PLAN

Hazardous Substances Spills

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Prespill Response Planning, Safety, and Assessment	Develop/demonstrate personnel safety devices (clothing, breathing apparatus)	●				
	Develop/demonstrate spills identification and detection kits (field kits and flow-through alarms)		●			
	Model spill plume movement in air, water, and soil				▲	
	Prepare emergency action manual for hazards in addition to fire and explosion			△	▲	
	Develop/update contingency planning guidelines	▲			△	▲
Containment and Confinement, Separation and Concentration	Demonstrate systems for treating soils (soil washer)	●	▲			
	Demonstrate second-generation containment systems on land (dike pak, portable tank)				●	
	Develop second-generation instream treatment systems (stream diverter)				●	
	Develop/demonstrate systems for separating substances from water (physical/chemical systems, reverse osmosis, steam stripping)				●	▲
	Develop/demonstrate systems for mitigation of air pollution				●	
	Prepare user manuals for spill control equipment and techniques			▲		▲
	Organize National Conference on Control of Hazardous Materials Spills		□		□	
Ultimate Disposal	Investigate mobile disposal systems for on-site detoxification of residuals		●		●	●
	Develop/demonstrate most promising disposal techniques				●	▲
Fate and Effects	Identify data gaps for hazardous substances				▲	
	Determine effects and persistency data				△	▲
Restoration	Identify gaps in knowledge on accelerated recovery of spill areas		▲			
	Develop/demonstrate restoration techniques		△			△ △
	Prepare and update restoration manual				△	▲

MUNICIPAL WASTEWATER RESEARCH PLAN
Oil Spills

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Prevention	Evaluate effectiveness of current oil SPCC regulations	▲				
	Develop guide for improved SPCC practices		▲			
Control and Cleanup	Demonstrate second-generation containment systems in water courses (jet boom)			●		
	Operate OHMSETT test facility	■	■	■	■	■
	Prepare user manuals for spill control equipment and techniques			▲		
	Develop new technology for shoreline protection and restoration			●		
	Organize National Conference on Control of Oil Spills	□		□		□
	Evaluate dispersants and other chemical and biological control agents		△	■	■	■
	Develop technology for cleanup of oil spills in cold climate weather conditions				●	
	Develop inexpensive technology for cleanup of spills under fast current conditions	△		●		

MUNICIPAL WASTEWATER RESEARCH PLAN
Emergency Spills Monitoring Systems and Quality Assurance

PROGRAM OBJECTIVES	R&D SUB-OBJECTIVES	FISCAL YEAR 81	82	83	84	85
Monitoring Systems and Quality Assurance	Conduct spill prevention control and countermeasures studies					■
	Develop aerial surveillance and analysis manual		▲			
	Continue emergency oil and hazardous material spill response, on-scene analysis, and briefings					■
	Develop quality assurance program					■
	Complete Alaska gas pipeline study		▲			
	Develop emergency response standard operating procedures manual		▲			
	Provide support to Office of Water Program Operations for spill prevention, hazardous waste-site support, and oil spills					■
	Provide remote sensing assistance, expert witnesses, and case preparation for Hazardous Waste Task Force, Office of Enforcement, and Regions					■

APPENDIX A
RESEARCH OPTIONS

The chapters in Research Outlook 1981 are based on the research plans developed by each of ORD's thirteen research committees. The following research scenarios describe how the research programs are likely to be affected by changing budget levels in the 1981-1985 period. For each program area, three budget projections are presented:

- no growth—maintains a steady funding level from 1982 on; however, such funding is in fact a modest reduction given an inflation rate of roughly 8.5%;
- moderate growth—provides a modest annual increase in funds from 1982 on in order to correct for an inflation rate of roughly 8.5%; and
- high growth—corrects for inflation and increases funding by an additional 10%.

In the following tables that present the projections, the 1981 figure is EPA's current budget estimate for this fiscal year; these estimates are subject to change as the year progresses. The 1982 figure for each "no-growth" scenario is the March, 1981, President's budget.

Energy and Environment

ENERGY
RESEARCH COMMITTEE

1981 Actual $104,938.8

GROWTH	1982	1983	1984	1985
NO	70,145.9	70,145.9	70,145.9	70,145.9
MODERATE	76,108.3	82,577.5	89,595.6	97,211.2
HIGH	83,122.9	98,500.6	116,723.2	138,317.0

Figures are in thousands of dollars.

No Growth. In order to keep pace with research demands in such increasingly high priority program areas as acid deposition and synthetic fuels, programs to determine fine particulate emission factors, to evaluate the cost/performance of wet flue gas desulfurization systems, and to perform environmental assessments of direct liquefaction processes will be reduced or eliminated.

In addition, research on the impacts from conventional power plants on aquatic ecosystems will be reduced, as will animal toxicology research on the health effects of energy-related pollutants.

Moderate Growth. The synthetic fuels, acid deposition, spills, and coastal ecosystems research programs will continue to receive the primary emphasis.

In the synfuels area, efforts to develop and promulgate pollution control guidance documents for all major synthetic fuel processes will be continued. These documents are intended to remove regulatory uncertainty by providing environmental guidance to environmental permit writers and to synfuel process developers. In addition, synfuel risk assessments will be conducted.

In the acid deposition program, the primary emphasis of the environmental engineering and technology research program will be the development of the limestone injection/multistage burner (LIMB) control process which is designed to simultaneously control NO_x and SO_2. The environmental processes and effects research program will continue to focus on dose-response relationships.

The major thrust of the oil spills program will be the development of protocols for freshwater and terrestrial ecosystems.

Finally, research on the impacts of energy development on coastal ecosystems will focus on the development of user manuals describing techniques for mitigating the damage of low-head/hydro plants, offshore oil and gas pipelines, and power transmission lines on ecosystems.

High Growth. In the environmental engineering and technology research program, efforts to reduce the environmental control costs for direct coal combustion and synthetic fuels control technology evaluation will be expanded. In addition, efforts to evaluate the environmental impact of the end use of synthetic fuels will be initiated. Efforts to demonstrate the costs and benefits of electrostatic-enhanced fabric filtration to control particulates will be accelerated. The field evaluation of full-scale or demonstration-scale synthetic fuel plants will be expanded to provide a reliable data base for pollution control guidance or regulations. Also, efforts to demonstrate the limestone injection/multistage burner process will be accelerated.

In the environmental processes and effects research program, the following research activities will be expanded:

- synfuels risk assessment
- damage assessments of hazardous and toxic spills

on freshwater and terrestrial ecosystems

- studies on the impacts of energy development on coastal ecosystems, e.g., peat mining in Louisiana
- studies of the contamination of groundwater supplies by acid precipitation, including a study identifying areas in the western United States that are sensitive to acid deposition.

Hazardous Air Pollutants

No Growth. Emphasis will be decreased on the development of short-term bioassay tests for detecting hazardous air pollutants. Also to receive less emphasis will be research to characterize ambient air in order to identify the biological activity, frequency of occurrence, chemical composition, and concentration of pollutants found in the ambient air.

Moderate Growth. The program will continue to emphasize research on comparing the effects and control of carcinogens with the effects and control of other hazardous air pollutants. In addition, major emphasis will be on ambient air characterization research as opposed to ambient air monitoring research.

High Growth. More refined risk assessments will be developed as will more cost-efficient control technologies. The number of site-specific field studies will be increased and more accurate monitoring systems will be developed for increasing the monitoring of organic pollutants in the ambient air.

HAZARDOUS AIR POLLUTANTS RESEARCH COMMITTEE

1981 Actual $11,552.4

GROWTH	1982	1983	1984	1985
NO	10,768.0	10,768.0	10,768.0	10,768.0
MODERATE	11,683.3	12,676.4	13,753.9	14,923.0
HIGH	12,760.1	15,120.8	17,918.1	21,232.9

Figures are in thousands of dollars.

Gases and Particles

GASES AND PARTICLES RESEARCH COMMITTEE

1981 Actual $30,487.1

GROWTH	1982	1983	1984	1985
NO	29,332.4	29,332.4	29,332.4	29,332.4
MODERATE	31,825.7	34,530.9	37,466.0	40,650.6
HIGH	34,758.9	41,189.3	48,809.3	57,839.0

Figures are in thousands of dollars.

No Growth. Clinical health studies and monitoring support will continue at present levels while reductions will occur in animal toxicology studies, ecological effects work, and regional haze modeling.

Moderate Growth. Emphasis will be on the development of receptor models as a means to evaluate SO_X/particle control strategies. Also of high priority will be the development of techniques to more efficiently operate and maintain existing pollution control equipment.

High Growth. A program of epidemiological studies will be developed along with increased efforts in regional haze modeling. Animal toxicology and ecological effects studies will continue at their present levels.

Oxidants

No Growth. Efforts to find improved ways to control emissions of volatile organic compounds (VOC) will increase while epidemiological and ecological studies of the effects of ozone and NO_2 will be reduced.

Moderate Growth. Research on low NO_X burner technology will be accelerated as will work on VOC control. The clinical health and ecological effects programs will remain at current levels.

OXIDANTS
RESEARCH COMMITTEE

1981 Actual $16,626.9

GROWTH	1982	1983	1984	1985
NO	18,076.0	18,076.0	18,076.0	18,076.0
MODERATE	19,612.5	21,279.6	23,088.4	25,059.1
HIGH	21,420.1	25,382.8	30,078.6	35,643.1

Figures are in thousands of dollars.

High Growth. In addition to the growth areas mentioned above, studies of the health effects of non-ozone oxidants (e.g., PAN, formaldehyde) will be undertaken. Technologies for control of these oxidants will also be studied. Increased efforts will take place to model dispersion of ozone across regions and to identify the level of natural precursors of ozone.

Mobile Sources

No Growth. Emphasis will remain on assessments of human exposure to motor vehicle pollutants and development of short-term screening tests for vehicle exhausts. Few resources will be available for epidemiological studies of human exposures to carbon monoxide and diesel exhaust.

Moderate Growth. Development of methods to isolate and measure mutagenic substances in motor vehicle exhaust will continue at their present levels. Efforts will focus on emissions from heavy-duty diesel engines and from engines powered by synthetic fuels.

High Growth. Epidemiological studies of the chronic effects of exposures to carbon monoxide can be undertaken. Studies will focus on cardiovascular effects.

MOBILE SOURCES
RESEARCH COMMITTEE

1981 Actual $8,829.0

GROWTH	1982	1983	1984	1985
NO	6,253.2	6,253.2	6,253.2	6,253.2
MODERATE	6,784.7	7,364.4	7,990.4	8,669.6
HIGH	7,410.0	8,780.9	10,405.3	12,330.3

Figures are in thousands of dollars.

Non-Ionizing Radiation

NON-IONIZING RADIATION
RESEARCH COMMITTEE

1981 Actual $3,167.0

GROWTH	1982	1983	1984	1985
NO	2,982.4	2,982.4	2,982.4	2,982.4
MODERATE	3,235.9	3,511.0	3,809.4	4,133.2
HIGH	3,534.1	4,187.9	4,962.7	5,880.8

Figures are in thousands of dollars.

No Growth. During the period FY 1982-84, a shift in research emphasis will be made due to completion of a series of projects to determine the health effects of environmentally significant frequencies of non-ionizing radiation. The research program will be continued, but at a slightly reduced level; the future studies will be geared toward research on the dose-response relationships and the effects of lifetime exposure to resonant frequencies. Also, ORD's ability to support a radiation quality assurance program will be severely curtailed.

Moderate Growth. The health program, with the shift in emphasis described above, will remain at a level of effort equivalent to the current health research program. Radiation quality assurance activities will be diminished.

High Growth. Radiation quality assurance will be increased to provide EPA with a quality assurance program commensurate with the needs of the Office of Radiation Programs.

Pesticides

**PESTICIDES
RESEARCH COMMITTEE**

1981 Actual $10,603.6

GROWTH	1982	1983	1984	1985
NO	6,875.5	6,875.5	6,875.5	6,875.5
MODERATE	7,459.9	8,094.0	8,782.0	9,528.5
HIGH	8,147.5	9,654.8	11,440.9	13,557.5

Figures are in thousands of dollars.

No Growth. Human and environmental exposure studies will be slightly decreased. Also, increasing demands for calibration materials will require a decrease in services provided by ORD's pesticides repository.

Moderate Growth. The research program will be maintained at its current level. Particular attention will be paid to support the increasing demand for repository services as well as the demand for data about human and environmental risk assessments.

High Growth. Research for human and environmental risk assessments will increase as will repository services to provide assistance commensurate with the needs of program demands.

Toxic Chemical Testing and Assessment

No Growth. Overall emphasis will continue on development, refinement, and application of methodologies for testing, characterizing, and evaluating the health and environmental fate and effects of chemicals. This includes developing test procedures to determine whether a given chemical requires further investigation, and if so, to provide relevant tests. The program will provide predictive capabilities for hazard assessments and will contribute to guidelines and protocols ensuring the adequacy of tests that may be used by industry. Both the monitoring and engineering research programs will contribute to the overall program by providing information related to chemical exposure. The monitoring program will continue to develop analytic methods for improved measurement techniques while the engineering program will provide analyses on environmental releases of chemicals.

Moderate Growth. The program will evaluate exposure levels and resulting hazard potentials to humans and the environment from a variety of pollutant concentrations and transport pathways. Molecular indicators of human exposure (i.e., for chemical represence and dose) will be studied for several classes of compounds. Studies of metabolism and target organs will be accelerated and expanded to include multiple species. Environmental exposure parameters including chemical release, fate, use, distribution, fugitive emissions, disposal, and resulting effects will be correlated in detail. Research for use in predictive and risk evaluations will be accelerated; emphasis will be on promising techniques such as the use of chemical structure/activity relationships. Monitoring technology will be improved, especially for multi-species detection and specification. Top priority will be given to establishing a quality assurance program specifically tailored to EPA's regulatory and enforcement activities.

High Growth. Both the health and environmental processes and effects program will undertake modeling

**TOXIC CHEMICAL
TESTING AND ASSESSMENT
RESEARCH COMMITTEE**

1981 Actual $35,518.5

GROWTH	1982	1983	1984	1985
NO	38,007.6	38,007.6	38,007.6	38,007.6
MODERATE	41,238.3	44,743.6	48,546.8	52,673.3
HIGH	45,039.0	53,371.2	63,244.9	74,945.2

Figures are in thousands of dollars.

that uses systems which take into account the multiple interactions of toxic chemicals as they move within and through the environment and as they affect receptor organisms, including humans. The health program will be based on structure-activity information being developed in the environmental processes program; the monitoring program will expand development of standardized protocols for validating the accuracy of predictive systems; the engineering research will establish a program to study the chemical industry. The stratospheric modification program will expand the research on the biological effects of increased ultraviolet radiation caused by ozone depletion including research on the effects on economically important food resources.

Solid Wastes

SOLID WASTE RESEARCH COMMITTEE

1981 Actual $29,642.6

GROWTH	1982	1983	1984	1985
NO	31,046.0	31,046.0	31,046.0	31,046.0
MODERATE	33,684.9	36,548.1	39,654.7	43,025.4
HIGH	36,789.5	43,595.6	51,660.8	61,218.1

Figures are in thousands of dollars.

No Growth. Major emphasis will be on identifying hazardous wastes and developing information for control technologies. Hazardous waste identification will initially focus on the development of sampling and analytical protocols, quality assurance, and evaluation of existing methods and procedures; later work will shift more toward waste characterization, exposure assessment, and the development of new sampling and analytical methods. Control technology research will develop the information base that will support the permitting program for hazardous waste. Particular attention will be paid to evaluating thermal decomposition, containment, and other hazardous waste treatments.

In support of Superfund legislation, the immediate effort will focus on development of guidance documents and the technical and scientific back-up for revising the National Contingency Plan. Methods will be developed for discovering, evaluating, and remedying releases or threats of releases; relative costs of remedies will also be analyzed. Criteria will be developed for determining the appropriate extent of removal, remedy, and other measures and for establishing priorities for action to deal with releases or disposal sites. Some effort will be devoted to establishing the scientific basis for determining the minimum quantity of hazardous wastes that would trigger a reporting requirement.

Moderate Growth. More emphasis will be on hazardous waste identification efforts described under the "no-growth" scenario in an effort to move more rapidly toward waste characterization, exposure assessment, and development of new sampling and analytical methods. Control technology research will intensify studies of thermal decomposition and containment. Risk assessments will be used to: (1) develop the criteria to support "listing/delisting" of hazardous waste; (2) adapt and develop techniques to assess ecological damage from disposal of hazardous waste; and (3) develop methods for measuring the bioenvironmental stress of hazardous waste.

For support of Superfund activities, research will be expanded to develop monitoring specifically for discovering and evaluating waste sites; included will be the improvement of remote sensing and the development of analytical methods and quality assurance procedures. An expanded program will develop procedures and methodologies for evaluation of health risks and natural resource damages associated with releases of hazardous materials.

High Growth. Because of the need to build a broad information base as rapidly as possible, research under the high-growth option will focus on the same areas of hazardous waste identification, control technology, and risk assessment described above but with the objective of producing critical results earlier than under the no-growth or moderate-growth options.

With respect to research support for Superfund, an accelerated program will develop guidance and the scientific basis for prioritizing sites in terms of the relative risk of human exposure and natural resource damage. A methodology will be developed for determining the cost effectiveness of natural resource restoration activities.

Drinking Water

No Growth. Major attention will be placed on supporting the EPA's groundwater strategy by: (1) accelerating transport and fate research in varying hydrogeologic regimes; (2) providing assistance for states and EPA Regions on technical requirements of the EPA groundwater strategy; (3) developing guidance for translating quality requirements into source control plans; and (4) determining quality criteria for non-drinking use of groundwater. Emphasis will also be on developing information to evaluate pollution control technologies that could serve small populations. Continued will be the current emphasis on determining the health effects of organic contamination in drinking water and developing the methods for controlling the contamination.

Moderate Growth. Research emphasis concerning groundwater will be on methods for monitoring trace organics and reclaiming aquifers contaminated by toxic chemicals. Greater emphasis will be given to determining health effects of synthetic organics and methods for organics control. Analytical methods to identify contaminants in drinking water will be developed or improved as appropriate.

High Growth. Groundwater research identified above will be accelerated. Health effects activities will center on identifying compounds and classes of compounds posing the greatest health risks and on assessing the potential extent of those risks. Control technology research will focus on the field evaluation of chemical contamination control systems to establish reliable cost and operating information.

DRINKING WATER
RESEARCH COMMITTEE

1981 Actual $26,344.5

GROWTH	1982	1983	1984	1985
NO	29,712.7	29,712.7	29,712.7	29,712.7
MODERATE	32,238.3	34,978.6	37,951.8	41,177.7
HIGH	35,209.6	41,723.4	49,442.2	58,589.0

Figures are in thousands of dollars.

Water Quality

WATER QUALITY
RESEARCH COMMITTEE

1981 Actual $27,399.9

GROWTH	1982	1983	1984	1985
NO	18,055.9	18,055.9	18,055.9	18,055.9
MODERATE	19,590.7	21,255.9	23,062.7	25,023.0
HIGH	21,396.2	25,354.5	30,045.1	35,603.4

Figures are in thousands of dollars.

No Growth. With a no-growth budget, criteria document support for the regulatory offices in this area will be reduced. Also decreased will be field sampling for toxics, research on effects of varying POTW levels, and short-term testing for carcinogens.

Moderate Growth. Water quality criteria document support will be reduced, as will comparative toxicology studies of aquatic and mammalian species.

High Growth. Risks to human health from polluted surface waters will be evaluated. We will also expand development and standardization of measurement methods, primarily for toxics; development and testing criteria for achieving water quality goals through integrated watershed management will also be increased.

Industrial Wastewater

No Growth. Efforts to develop analytical methods for specific pollutants and to improve the reliability of conventional methods of treatment will be diminished significantly in order to: (1) support critical on-going efforts to develop innovative concepts for controlling toxic pollutants that are presently poorly controlled, and (2) support the Agency's permitting activities. Research for these two areas will include: work on the toxicity reduction concept as a means of simplifying permit issuance and compliance, a search for alterna-

INDUSTRIAL WASTEWATER RESEARCH COMMITTEE

1981 Actual $15,305.5

GROWTH	1982	1983	1984	1985
NO	10,597.9	10,597.9	10,597.9	10,597.9
MODERATE	11,498.7	12,476.1	13,536.6	14,687.2
HIGH	12,558.5	14,881.8	17,634.9	20,897.4

Figures are in thousands of dollars.

tives to the costly measurement of numerous individual industrial pollutants, the revision and update of the Treatability Manual, and improvement of the capability and extension of the applicability of existing treatment and control methods.

Moderate Growth. Work will be continued on improving analytical and monitoring methods for specific toxic pollutants and on improving reliability of existing treatment systems. Modest efforts over the next 5 years will assess wastewater problems of emerging industries and will investigate innovative approaches to more cost-effective means for industry to comply with discharge limitations. In addition, continued work in support of program office activities will be possible, including research on toxicity reduction and treatability.

High Growth. Beginning efforts will pursue the development and demonstration of more cost-effective and energy-efficient methods for the control of industrial pollution. Innovative concepts, including raw material and process modification, centralized treatment and recycle/reuse, will be studied. New concepts in monitoring and measurement methods, specifically including biomonitoring approaches, will be investigated and demonstrated; such methods will allow simpler and cheaper compliance with discharge requirements. Net "deposits" into the industrial pollution control "information bank" will be made as opposed to the net "withdrawals" of information which have occurred in the last decade.

Municipal Wastewater Pollution Control and Spill Prevention

No Growth. Major emphasis will be on control technology research to develop and evaluate innovative and alternative technologies. Particular emphasis will be on developing and evaluating the operation and maintenance of the technologies and their energy efficiencies.

Moderate Growth. Major emphasis will continue to be on control technology; further effort will be on development and demonstrations of technologies for aquaculture. Health issues associated with the land application of sludge and the reuse of municipal wastewater will also be addressed, although resources allocated to this latter area will be very low.

High Growth. Major emphasis will focus primarily on providing expert technical support and development of new or improved on-site wastewater management systems. Attention will be on developing improved analytical protocols for toxic materials in municipal wastewater, determining the fate of toxic pollutants in publicly owned treatment works and developing control options and technologies to limit the discharge of toxic pollutants to the environment. Research at a very low level will also be conducted concerning urban runoff that relates to pollution problem assessment and infiltration/inflow rehabilitation.

MUNICIPAL WASTEWATER RESEARCH COMMITTEE

1981 Actual $20,175.6

GROWTH	1982	1983	1984	1985
NO	19,384.9	19,384.9	19,384.9	19,384.9
MODERATE	21,032.6	22,820.4	24,760.1	26,864.7
HIGH	22,971.1	27,220.8	32,256.7	38,224.19

Figures are in thousands of dollars.

APPENDIX B
INTERAGENCY COORDINATION

Environmental and development is conducted by 16 federal agencies, at a cost of more than $2 billion a year. Many of these research and development programs involve interagency cooperation and coordination to prevent the costly and unnecessary duplication of research efforts. Such interagency research helps bring the best possible expertise to bear on pressing environmental problems and helps ensure the optimal use of the research products generated by these programs. Existing agreements between agencies are constantly being reevaluated, and, where appropriate, new ones are being initiated.

The following discussion of EPA's interagency projects is only a partial listing of the Agency's interagency effort, and is intended to serve as an example of the types of cooperative research in which EPA is involved.

Interagency Energy and Environment Research Program (IEERP)

In 1975, an Interagency Energy and Environment Research Program (IEERP) was established following a special congressional appropriation for energy-related health and environmental effects research. Since 1978, EPA has served as the coordinator and implementer of this effort, working to develop an integrated, comprehensive research program, one that is scientifically defensible and cost effective as well as responsive to the research needs of all of the participants in the program. Along with the EPA, the following agencies are lending their expertise and their unique facilities to this effort:

National Science Foundation
National Institute of Environmental Health Sciences
National Institute of Occupational Safety and Health
Department of Energy
National Oceanic and Atmospheric Administration
Tennessee Valley Authority
National Aeronautics and Space Administration
Department of the Interior
Department of Agriculture
National Bureau of Standards

In FY 1980, approximately $31 million was passed through IEERP to these agencies for research on the health and environmental effects of energy-related pollutants.

Interagency Committee for Stratospheric Ozone Protection (ICSOP)

The Interagency Committee for Stratospheric Ozone Protection, established under the Clean Air Act, consists of representatives from 12 federal agencies, each of which is responsible for various aspects of research and monitoring related to the stratosphere, particularly stratospheric ozone. The major research interest of the Committee is the effects that stratospheric ozone depletion may have on life and the environment.

The ICSOP is chaired by the EPA Assistant Administrator for Research and Development, and is made up of three subcommittees through which the member agencies coordinate their relevant research and monitoring programs. The subcommittees are: (1) atmospheric sciences, (2) health effects, and (3) biological and ecological effects that pertain to stratospheric ozone and ultraviolet radiation. To date, the subcommittees have developed research plans designed to fill important knowledge gaps, improve data quality, and reduce scientific uncertainties, all three serving to strengthen the scientific base that supports policy decisions. The plans have been recommended to the responsible agencies and selected projects are currently being considered for funding.

National Center for Toxicologic Research

The National Center for Toxicologic Research (NCTR), located in Jefferson, Arkansas, is a unique facility equipped to conduct long-term toxicologic studies using large numbers of animals. Supported jointly by ORD and the Food and Drug Administration, it conducts research on a number of health effects endpoints of concern to EPA. These include: mutagenesis, immunotoxicology, biochemical mechanisms of toxicity, and reproductive and developmental toxicology. While investigating these endpoints, the Center also conducts studies on the potentially synergistic or antagonistic effects of exposures to multiple compounds. Programs in risk estimation, including one for carcinogenicity, are also a feature of the Center's research activity, as are projects that are seeking to establish the most valid ways of extrapolating animal data to people.

Neurotoxicology Program

A joint neurotoxicology program involving ORD and FDA was established in 1979 to shed further light on recent evidence that has indicated that exposure to toxic chemicals may be associated with a variety of health disorders, including effects on the brain, nervous system, and on behavior. The evidence has also suggested that such neurotoxicologic effects were important parameters in evaluating chemicals for their potential health risks. The program will strengthen the research efforts of both organizations, and working with the evidence will implement new studies to make significant inroads into the relatively young field of chemical neurotoxicology.

Three major study areas characterize the program's current research effort. The first area involves the examination of neurotoxicants to determine how exposure during early life stages affects the size and shape of the developing brain. This information will, in turn, help establish whether brain morphometrics may be used as a criterion for neurotoxicity. The second area of effort involves research into the effects of chemicals on neurophysiologic endpoints, including nerve conduction. The final study area is attempting to establish the correlation between exposure to neurotoxicants and effects on both behavior and brain chemistry.

Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP)

The Office of Science and Technology Policy (OSTP) and the Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP) staff, along with significant assistance from ORD, are updating a report that summarizes the problems of hazardous waste management and that outlines the scientific and technical needs for better addressing waste problems. The updated report, which identifies hazardous waste management as a continuing high priority problem faced by state and local governments, recommends the specific existing knowledge that should be applied to the problem as well as the types of research and technology development that should be undertaken over the next five years (FY 1981-85) to achieve significantly more effective management of hazardous wastes. A new section of the report on ecological processes and effects will address the problem of the uptake of hazardous waste contaminants by the food chain.

A number of recommendations from the original report are retained in the updated version. These include:

(1) the call for improved data and procedures for defining wastes and waste sites in terms of the degree of hazard they pose to human health and the environment;

(2) the development of new and improved technologies capable of destroying or detoxifying both future waste streams and waste mixtures already present in problem sites;

(3) the setting of criteria for the siting of new facilities; and

(4) the establishment of an environmental research center dedicated to the study of hazardous waste problems (proposed by ORD to occur during FY 1981).

In preparing the updated report, OSTP is reviewing federal hazardous waste research activities; EPA is interviewing numerous state and local government representatives involved with hazardous waste management. In the future, several of the ORD laboratories where EPA's hazardous waste research is being conducted will also be visited.

The considerable cooperation between EPA, OSTP, and ISETAP that has been shown to date has enabled researchers to gain significant insights into solid and hazardous waste problems and research needs. These, in turn, are now being integrated into EPA's own multifaceted hazardous waste research program. It is expected that in the years to come, this cooperative posture will be maintained and that EPA will continue to work with OSTP and ISETAP to help structure its own research program while at the same time acting as a reviewer of this key interagency effort.

Task Force on Environmental Cancer and Heart and Lung Disease

The Task Force on Environmental Cancer and Heart and Lung Disease, established in 1977 by Public Law 95-95, is at the vanguard of the national attack on environmentally related cancer and heart and lung disease. The Task Force was directed by Congress to recommend comprehensive research programs that would first, quantify the relationships that exist between environmental pollution and human cancer and environmental pollution and heart and lung disease, and second, reduce the risk and incidence of such diseases. Additionally, the Task Force was called on to stimulate cooperation in this effort among federal agencies, coordinate all relevant research, and report annually to Congress on the progress and difficulties in reaching program objectives.

The Task Force, chaired by EPA, is made up of representatives from:

- National Cancer Institute;
- National Heart, Lung and Blood Institute;
- National Institute for Occupational Safety and Health;
- National Institute of Environmental Health Sciences;
- National Center for Health Statistics;
- Center for Disease Control; and
- Food and Drug Administration.

Since the Task Force's inception, ORD has actively participated in the formal Task Force, as well as in each of its three interagency subcommittees, referred to as Project Groups: Education of the Public and of Health Professionals, Exposure and Metabolic Mechanisms, and Standardization of Measurements and Tests.

During FY 1978, the Task Force defined the problems confronting researchers and the subject matter to be studied. Relevant research programs were examined and inventoried, and information was categorized. Areas of special interest were identified and the Project Groups were formed to initiate work in these areas. Ongoing studies in risk assessment and in the costs of environment-related disease were reviewed, and numerous information exchange and coordination activities were established among Task Force agencies, as well as among the Task Force and other agencies and interagency groups.

During FY 1979, the Task Force continued its efforts through the Project Groups and other activities. Results to date have included a preliminary interagency inventory of research programs, formal research recommendations, information exchange programs, and a number of reports.

A key accomplishment during FY 1980 was the development and refinement of an inventory of information gained from the research programs of eight agencies. The inventory was subsequently used to identify those scientific areas where increased research is warranted to quantify the relationships between environmental pollution and human cancer and heart and lung disease. Initial program recommendations that evolved from this first-stage identification process pointed to the need for expanded study in four areas:

- multimedia pollutant exposure and health effects;
- transport and fate of pollutants in the biosphere and the food chain;
- biological and chemical measurement methodology and data analysis; and
- pollutants in ground and surface water sources.

The research program inventory was also useful in defining Project Group study areas that required increased attention.

Also receiving major Task Force emphasis was the exchange of information among member agencies and other appropriate entities. Activities included: (1) interchanging information on data bases, risk assessment, and disease costs; (2) communicating with relevant federal agencies and interagency groups, committees and programs; (3) providing support for the collection and coordination of statistical and epidemiological data on environmental health; and (4) publishing a monthly calendar and several data base and interagency group directories.

Project Group activity was significant in FY 1980. The Exposure and Metabolic Mechanisms Project Group worked to identify research needs and develop research strategies to address these needs, while the Standardization of Measurements and Tests Project Group devised an approach to validate the accuracy and precision of chemical measurements used to quantify the relationship between a given environmental pollutant and human cancer and heart and lung diseases. In addition, studies were conducted to determine the feasibility of improving data quality and utility.

During FY 1981, the Task Force will expand its information exchange activities. The coordination of activities with other agencies and interagency groups also will be strengthened and systematized. Needs relating to coordination, accessibility, and availability of information of concern to the Task Force will be identified, monitoring of risk assessment activities will be continued, and Project Groups will persist in their efforts to define those areas that require further study and the subsequent feasibility of interagency activities for this research.

The program inventory will be further developed and updated, making use of the improved forms and procedures that were initiated for the first-stage study conducted during FY 1980. Based on these study findings, the updated inventory, and on the recommendations developed by other planning groups, the Task Force will then formulate its own specific recommendations for both a comprehensive research program and for strategies to reduce the risk and incidence of environmental cancer and heart and lung disease.

Acid Precipitation Task Force

The Acid Precipitation Task Force, which in June 1980 replaced the Interagency Acid Rain Coordinating Committee, was established by Congress in Section 701 of the Energy Security Act. The Task Force is jointly co-chaired by the Administrator of the Environmental Protection Agency, the Administrator of the National Oceanic and Atmospheric Administration, and the Secretary of the Department of Agriculture. Its overall goals are: to develop and implement a comprehensive 10-year plan to identify the causes and sources of acid precipitation; to evaluate acid precipitation's environmental, social, and economic effects; and to identify actions to remedy or ameliorate its harmful effects. The first draft of the comprehensive plan was delivered to Congress in December 1980, with subsequent reports detailing the progress of the plan to be submitted annually.

Indoor Air Quality Interagency Group

In February 1980, the Interagency Group on Indoor Air Quality was established to develop and coordinate the multiagency research effort on indoor air pollution. The research group consists of representatives from:

Environmental Protection Agency
Department of Housing and Urban Development
Department of Defense
National Bureau of Standards
Consumer Product Safety Commission
National Aeronautics and Space Administration
National Institute of Environmental
  Health Sciences
Occupational Safety and Health Administration

A number of working groups are being formed to help coordinate related research activities, to review interagency priorities in light of the January 1981 National Academy of Sciences' report on the indoor environment, and to conduct technical reviews of ongoing and recently completed research. Working groups already established are those concerned with planning and coordination, monitoring, instrumentation, controls, and health effects.

Committee on Ocean Pollution Research and Development and Monitoring

In May 1978, President Carter signed Public Law 95-273—the National Ocean Pollution Research and Development and Monitoring Planning Act. This act required that the Executive Branch "establish a comprehensive 5-year plan for federal ocean pollution research and development and monitoring programs in order to provide planning for, coordination of, and dissemination of information with respect to such programs within the federal government."

Specifically, the plan is required to include:

- a detailed inventory of existing federal programs;
- an assessment and ordering of national needs and problems;
- an analysis of the extent to which existing programs assist in meeting these priorities;
- recommendations for changes in the overall federal effort where appropriate or necessary; and
- a report on budget coordination efforts.

Responsibility for preparing this plan falls to the Administrator of the National Oceanic and Atmospheric Administration (NOAA), following consultation with the President's Office of Science and Technology Policy and other federal agencies involved in ocean pollution research, development, and monitoring activities.

To gather and analyze most of the information required for preparation of the plan, the President's Federal Coordinating Council for Science, Engineering, and Technology created an interagency Committee on Ocean Pollution Research, Development, and Monitoring (COPRDM) in June 1978. NOAA's Deputy Administrator serves as chairperson of COPRDM; EPA's Assistant Administrator for Research and Development is vice chairperson.

The first plan was submitted to Congress early in 1979 and will be updated every two years with the next update scheduled for presentation in September 1981. In addition to the specific information required by law, this second federal plan will include an agency-by-agency breakdown of each group's five-year plan for ocean pollution research. Also part of the plan will be a comprehensive critical review of all existing federal research and development related to marine oil pollution and hazardous chemical spill response technology.

APPENDIX C
GLOBAL ISSUES AND INTERNATIONAL COOPERATION

The Environmental Protection Agency recognizes the need to protect our nation from pollution generated by neighboring countries, as well as the need to join others in protecting the global commons. EPA therefore engages in a variety of international activities aimed at reducing transboundary and global pollution, while, concurrently, obtaining technology and expertise for solutions to domestic environmental problems.

The Office of Research and Development often plays an important role in these endeavors. We are called upon to lend expertise and provide technical assistance in a wide variety of cases ranging from monitoring air and water quality to working with foreign governments on environmental control legislation and regulations. However, since EPA's primary role is that of a domestic regulatory agency, domestic environmental concerns have traditionally been reflected in the type and amount of research dedicated to international activities. Nevertheless, pollution problems of international dimension require the Agency to seek solutions through international activities and cooperation.

This cooperation has provided us with opportunities to learn from others. One of the most significant opportunities has been in the area of environmental control technology development that, in several countries, has reached a more advanced stage than in the United States. For example, EPA's air regulatory program has been enhanced because sophisticated Japanese technology for controlling NO_X and SO_X can be applied to American utility operations with reliable results at reasonable costs. Also, EPA was able to evaluate and copy Germany's 15-year-old hazardous waste management system and was thus better able to design a U.S. system based on the German model. Working with other nations has also provided unique opportunities for gathering environmental information. For example, from Canada we are learning a great deal about acid rain, and with the Netherlands we are sharing lessons learned from the tragedies of Love Canal and Lekkerkerk.

To further beneficial international cooperation, a committee on foreign environmental science and technology (CFEST) has recently been created to oversee the exchange of information and to establish regular procedures for technology transfer. The committee is composed of representatives from various EPA offices and is chaired jointly by the Office of International Activities and the Office of Research and Development. CFEST will identify key Agency priorities for environmental science and technology and will monitor important foreign developments pertinent to those priorities. The committee will be used to complement the work of EPA's program offices in evaluating scientific advances and will assist in the actual transfer of the technology between the United States and other countries.

The countries with which American research now interfaces most heavily are the industrialized countries, particularly Norway, France, Germany, Sweden, the Netherlands, Great Britain, and Japan. For example, through scientific exchanges the Japanese have provided us with valuable technology for reducing air pollution and for treating solid waste. To facilitate interfaces with other countries, notably Egypt, Poland, Yugoslavia, India, and Pakistan, the Scientific Activities Overseas Program, financed by a special United States currency program, has been established. For our two neighboring countries, Canada and Mexico, information exchanges reflect the mutual need to deal with common border issues of air and water pollution.

EPA also conducts research activities with several multilateral organizations such as the Organization for Economic Cooperation and Development (OECD), Economic Commission for Europe (ECE), Committee for the Challenges of a Modern Society (CCMS), and United Nations Environment Program (UNEP). From a NATO/CCMS pilot study, the United States has gained important technology for the advanced treatment of wastewater; EPA is currently participating in 8 of 16 NATO/CCMS pilot studies for the exchange of technology and information about air and water pollution, plastics recycling, integrated pest management, and management of estuarine systems.

EPA also recently participated in the Presidential Task Force on Global Resources and the Environment to follow up on the Global 2000 report, a study of projections about the state of the environment and natural resources in the year 2000. The report addressed many important issues including atmospheric pollution, the stratosphere, toxic substances, and marine resources. EPA will continue to improve the ability to forecast environmental concerns and to help resolve global environmental problems.

A number of environmental research and development issues are and will remain in the forefront of EPA's international research effort over the next several years. The following topics are representative of the diverse areas in which we will be involved; however, our cooperative efforts in international research and development cover many more programs than discussed in this Research Outlook.

The Long-Range Transport of Acid Rain

The movement of air pollution across national boundaries is one of the most significant environmental issues being dealt with on the international level. Acidity measurements and studies conducted by Scandinavian countries since 1970 have confirmed the correlation between the transport, transformation, and deposition of sulfates and nitrates and the high acidity in Swedish and Norwegian rivers and lakes. The exact sources of the emissions causing this problem have not been pinpointed; however, sources in Great Britain, West Germany, Poland, and other parts of Europe have been implicated.

The acid rain phenomenon has subsequently been identified in other parts of Europe as well as in the United States and Canada. The most significant international aspect of the problem is that, due to the long-range transport of pollutants, the amount of pollution falling in one country is often determined by the pollution control policies of another. Thus, resolution of the problem requires that, first, all parties involved must understand the scope of the problem and the costs and benefits to each country in controlling it. Secondly, the parties must then mutually agree to develop a joint program to control sources that contribute to the problem.

To take even the first step requires both a substantial research effort to develop quantitative relationships between the emissions, their transport, and the fate of the acid rain, as well as an extensive analysis of the damages-versus-abatement costs inherent in different international solutions. To this end, we will continue to work with the ECE on the control of long-range transport of air pollution and with Canada on joint studies of acid rain transport and on talks leading to air quality agreements. In August 1980, the U.S. and Canada signed a Memorandum of Intent committing both governments to develop a bilateral agreement to combat transboundary air pollution. The Agreement can be expected to improve present efforts for coordinating research and sharing information between the two countries.

Global Atmospheric Pollution

One of the earth's most common chemicals, carbon dioxide, may turn out to be its greatest environmental threat. Although not directly toxic, CO_2 emissions are of major concern because of their potential effect on the world climate. Accumulating scientific evidence indicates that the steadily increasing concentration of CO_2 in the atmosphere may induce significant global meteorological changes. This could in turn have far-reaching political, social, and economic consequences for the world.

The concentration of CO_2 in the global atmosphere has increased about 15 percent in the last century, due mainly to the burning of fossil fuels. If the 2 percent per year increase in fossil fuel combustion continues as projected, CO_2 concentration in the atmosphere could double around the middle of the next century; other factors (e.g., tropical deforestation) could accelerate this trend.

The current scientific theory about atmospheric CO_2 (the "greenhouse effect") is that when sunlight hits the earth's surface and rebounds at infrared wavelengths, atmospheric CO_2 prevents this heat radiation from escaping back into space. Thus as the concentration of atmospheric CO_2 increases, so will average global surface temperatures; a 2-3° C temperature increase in the middle latitudes and a 5-10° C increase in the polar regions is projected if CO_2 emission trends are sustained.

Such a rapid warming trend could cause significant alterations of global precipitation patterns and widespread disruption of agriculture. The heating of the polar regions could eventually melt the polar ice caps, raising the sea level around the world and, perhaps, forcing abandonment of many coastal cities.

While the theory underlying the greenhouse effect is based on sound scientific principles, many questions remain unanswered. For example, it is not clear whether natural mechanisms, such as absorption in the ocean or increased plant growth, may offset an increase in atmospheric CO_2. There are also questions about the effectiveness of atmospheric CO_2 to block infrared radiation.

International research studies focus on finding answers to these scientific questions. The World Climates Program, established by the 8th World Meteorological Congress in 1979, and the United Nations Environment Program are conducting ongoing research programs about the global CO_2 problem. EPA has been keeping abreast of these activities and, if resources permit, may participate in them in the future.

Stratospheric Ozone

A problem of global concern is the predicted depletion of the stratospheric ozone layer which shields the earth from harmful ultraviolet radiation.

Man-made chlorofluorocarbons (CFCs) are the suspected culprits for the depletion. Two 1979 reports by the National Academy of Sciences indicated increased scientific confidence that CFCs do deplete stratospheric ozone and that this depletion is likely to have adverse health, ecological, and climatic effects. These and other American reports are in basic agreement with assessments by other countries and by UNEP and OECD. EPA research and policy officials continue to participate in meetings of the OECD Environment Committee, the UNEP Coordinating Committee on the Ozone Layer, and international scientific meetings to discuss research findings on ozone depletion and its effects. UNEP and OECD are also convenient forums in which we can gather and analyze CFC production and use data as well as exchange information about methods to reduce CFC dependence.

There is a lag of many decades between production of CFCs and their destruction of stratospheric ozone. Furthermore, it is not possible to detect small, man-induced changes in average ozone concentration levels with present measurement and analytical capabilities and with the large natural fluctuations of ozone levels. For these reasons, decisions about controlling world CFC production and growth must be made before actual CFC depletion of ozone is detected. Studies funded by EPA to model ozone depletion will continue for various scenarios of emissions and control actions. This modeling effort will be coordinated with the OECD and with modeling being done in other countries.

We are continuing domestic research into health and ecological effects of ozone depletion; the research is funded and administered by the Office of Research and Development. As part of a broader effort, our research will be coordinated with health effects research in the Netherlands and the Federal Republic of Germany.

Toxic Substances and Pesticides Testing and Control

The passage of the Toxic Substances Control Act (TSCA), which establishes a system for inventorying, testing, and controlling certain chemicals, is evidence of our national concern about toxic substances. The legislation is of international significance because it applies equally to domestic production and to imports; nations exporting certain chemicals and toxic articles to the United States must comply with specific regulations if our markets are to remain open to them. Furthermore, TSCA has a procedure for notifying receiving countries of exports banned or restricted under the Act.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which provides a framework for pesticide regulation to protect man and the environment from harmful effects of pesticides while still allowing their use, also has international provisions. Imported pesticides must meet the registration, testing, and labeling requirements of domestic pesticides; exported pesticides not registered in this country have packaging, labeling, and notification requirements. In addition, EPA notifies foreign governments of cancellations and suspensions under FIFRA.

Our international research efforts for testing and controlling toxic substances and pesticides focus principally on test development, safe disposal and cleanup methods, and health effects. We will be working primarily with the following organizations and countries:

- Organization for Economic Cooperation and Development—the principal international forum for cooperation on toxic substances issues;
- NATO Committee on the Challenges of Modern Society—to study methods for handling and disposing of hazardous wastes and to participate in a pilot study on integrated pest management;
- International Maritime Consultative Organization (IMCO)—to regulate the incineration of toxic substances at sea;
- World Health Organization (WHO)—to develop health effects criteria documents for specific chemicals, noise, and radiation and a new chemical safety program; to develop and apply risk assessment techniques; to review residue and toxicological data and recommend tolerances; and to evaluate health effects and environmental fate of certain chemicals and environmental contaminants (EPA cooperates with WHO under a Memorandum of Understanding);
- Food and Agriculture Organization (FAO)—to develop background criteria for acceptable limits of pesticide residues on food, in cooperation with WHO under the joint WHO/FAO expert committee, which advises the Codex Alimentarius Commission;
- United Nations Environment Program—to participate in the development and maintenance of the International Register of Potentially Toxic Chemicals, that lists quantities of new chemicals

introduced into the environment; the program also publishes technical reports about toxic chemicals;

- Italy—to follow and evaluate the progress of cleanup and the health effects of the Seveso dioxin contamination; and
- Japan—to develop technology for dredging bottom sediments containing toxic substances and to exchange information on the identification and control of toxic substances.

Marine Resources

The last few decades have seen fundamental changes in the way man uses and impacts upon the living and inanimate resources of the sea. Growing populations and increased demand coupled with advances in commercial fishing technology have led to intensified exploitation of fisheries. The continued exhaustion of land-based oil resources has resulted in the development of a major off-shore oil industry. Serious consideration is now also being given to mining the deep sea bed for nickel, copper, manganese, and other minerals. Finally, accelerated ocean transport of oil and other materials has greatly increased the potential for harmful spills.

Beyond the problems posed in maintaining stocks of commercial fisheries, we must ensure that the yield of these fisheries remains fit for human consumption. It is known, for example, that many aquatic and marine species, such as mollusks, can accumulate and concentrate trace quantities of metals or toxic substances to levels which threaten human health. The movement of these species ignores national boundaries, making it a problem of international scope.

The exploitation of ocean resources can also raise issues that require worldwide cooperation and control. Only recently, for example, a catastrophic eruption of the Ixtoc I oil well in Mexico's Bay of Campeche created an oil spill which eventually washed up on United States shores. The intensive multinational drilling in the North Sea, whose waters touch the shores of Norway, France, Denmark, Germany, the Netherlands, and the United Kingdom, also creates the potential for a severe ecological disaster with significant international ramifications. Clearly, then, such operations must be carried out in a way that minimizes the chances for such disasters.

Ocean dumping is also an important international problem. EPA is the primary United States representative to the London Ocean Dumping Convention which sets international rules governing the dumping of radioactive wastes, industrial chemicals, and sewage into the world's oceans.

Mining the sea bed also raises the potential for environmental damage, though it is uncertain how such damage would be manifest. One possible effect of tampering with the ocean bottom might be an alteration in the overall productivity of seas; however, much remains to be learned about the sensitivity of this ecosystem. It is also thought that the large-scale disturbance of bottom sediments might affect pelagic fish life or temperature and current patterns. Furthermore, at least as important as the bottom disturbances are chemical tailings from the mining discharged to the upper layers of the sea's waters.

Also posing a threat of international scope is the growing ocean-going trade of petroleum and other chemicals. Large-scale accidental spills such as those recently involving the supertankers *Amoco Cadiz* and the *Argo Merchant* have significantly disrupted local ecosystems, and raised significant public concern.

Focal points for our marine research are:

- CCMS—Pilot study on management of estuarine problems using the Chesapeake Bay and determining problems associated with competing uses;
- IMCO—Regulations to prevent tanker spills;
- Intergovernmental Council for Exploration of the Seas (ICES)—Special studies, e.g., environmental impacts of the *Amoco Cadiz* spill; and
- Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)—Special studies, e.g., vessel discharges of hazardous chemicals.

Radioactive Waste Management

As more nations turn to nuclear power as an energy source, the issue of the safe and environmentally sound disposal of nuclear wastes will become increasingly important. This is a multi-faceted issue that involves both the management and disposal of spent fuel and other high- and low-level radioactive wastes. A significant international corollary to the nuclear waste problem is that some of the radioactive material produced could be used to make nuclear weapons. The likelihood of proliferation of nuclear weapons could be lessened by careful choices between various waste management alternatives.

At present, there is a steadily growing accumulation of spent fuel at operating nuclear power plants. In the very near future, the amount of this spent fuel will exceed the storage space available at reactors.

Although the immediate problem could be handled by building more on-site storage space, by constructing off-site interim storage facilities, or by moving the spent fuel to reprocessing plants, none of these options really solves the waste problem. Reprocessing has an added disadvantage in that one of its products is weapons-grade plutonium. Ultimately, permanent disposal is the only real solution to the accumulation of spent fuel.

In addition to spent fuel, there are other high-level radioactive by-products of nuclear power generation. Although comparatively small in volume, such long-lived radioactive wastes require heavy shielding and remote handling, and must be kept in isolation for thousands of years. High-level wastes are an international problem because the improper disposal of nuclear wastes in one country could result in the spread of radioactivity to other countries. While there are several disposal options under consideration that make use of stable geological structures, suitable disposal sites may exist only in a few places around the globe.In addition, countries possessing only one or two reactors may find it uneconomical to develop their own national disposal facilities.

Low-level nuclear waste is a catch-all term referring to the dilute waste streams produced in the nuclear fuel cycle or the contaminated materials generated by the handling of radioactive substances. However, wastes containing long-lived transuranic nuclides are also sometimes included under the low-level rubric, even though the risk they pose is far from low level.

Regardless of the level or type of radioactivity, precautions must be taken to keep this material from entering biological pathways where it could be reconcentrated to hazardous levels. In the past, low-level wastes in the United States have been disposed of at commercially-operated landfills. The performance at these landfills has generally not been satisfactory, however, and has led to the new regulations currently being formulated by the Nuclear Regulatory Commission, with EPA assistance.

While the land disposal of low-level waste is the most common practice, a number of European countries also dump nuclear waste into the Atlantic Ocean. The environmental impact of this practice on the ocean commons is not fully known, therefore the United States does not now engage in ocean disposal of radioactive wastes, although EPA is required by the 1972 Ocean Dumping Act to study ocean dumping as a future waste disposal option.

EPA is the lead agency within the federal government for implementing the London Dumping Convention, an international treaty that is the primary mechanism for controlling ocean disposal of radioactive wastes. EPA also actively participates in the work of the OECD Nuclear Energy Agency (NEA) for site assessment and monitoring of the Northeast Atlantic Dumpsite, and in the International Atomic Energy Agency (IAEA) efforts to strengthen international rules and standards for ocean dumping of nuclear wastes.

In the future, EPA will continue its involvement in the following international efforts currently underway to deal with nuclear waste issues:

- IAEA—to develop criteria and standards for land-based radioactive waste management, and to strengthen and refine IAEA definitions and recommendations regarding sea disposal of radioactive wastes;
- NEA—to develop guidelines for high- and low-level waste disposal, and to continue monitoring and assessment of ocean dumping practices; and
- London Convention Consultative and Expert Meetings—to strengthen international controls on the sea disposal of radioactive wastes, and to ensure widespread acceptance and effective compliance with such controls.

Development and Environmental Planning

One of the important problems underlying the implementation of international environmental programs is the reconciliation of such programs with the specific national and international needs and development plans of individual nations. Still, no country operates in an environmental vacuum. Whether it be protection of endangered species, prudent use of marine resources, or control of pollutant discharges into the global commons, the environmental actions of one country will influence those of others.

So do economic actions. Over the last decade, the economic interdependence of countries has increased and, while industrialized nations seek to adjust to new patterns of trade and economic growth, developing countries are becoming more and more committed to raising their standards of living. Further complicating the situation are medium-developed countries such as Brazil and new nations such as Bangladesh, each with its unique national problems and objectives. It is impossible, however, to separate national problems from the state of the international physical environment.

For many countries the fundamental problem is one of survival. Overpopulation in lands of marginal productivity has already created large areas of severe soil exhaustion, desertification, and deforestation. Thus, with few resources to sustain them or to trade for the necessities of life, these countries must develop plans to conserve existing land, water, and fuel and to live with adverse demographics. In some cases, these plans may involve applying new technologies, but in others, reaching national goals may require large-scale resettlement and societal change. In doing so, there is often a significant threat to the environment. To make rational planning decisions for their economic future, these countries must have national planning models capable of predicting economic, social, and environmental costs and benefits offered by a variety of development plans.

Circumstances will inevitably lead different countries to seek different kinds of planning tools. What is ultimately required on a broad scale are highly flexible models capable of working on the local project level as well as on national and international development plans. In addition, means to incorporate environmental concerns into decision-making processes must be found. Several approaches to this are possible. For example, the Polluter Pays Principle, adopted by the OECD, employs economics as a method to shift decisions in the direction of environmentally favorable alternatives. Other techniques involve mediation and arbitration. The methods of control and regulation adopted by each country will reflect the individual circumstances and characteristics of the nation.

Through international programs such as the United Nations Environment Program and the World Health Organization, EPA participates in programs for developing nations. For example, under the auspices of WHO, EPA scientists frequently join delegations to study environmental health problems in developing countries. Because of its resource constraints, however, EPA has limited research activities in developing nations. In Egypt, EPA is assisting researchers in ambitious studies of river and lake management for the Nile River and the Aswan Dam. Also, with the Egyptians, EPA is engaged in a joint project on the analysis and management of desert ecosystems. Research cooperation between Nigeria and EPA will be fostered by a recently signed Memorandum of Understanding that will lead to several joint projects of environmental assistance and scientific exchange. In India, EPA has conducted several workshops outlining future cooperative programs, and the Agency has signed an agreement with China for joint projects on air and water pollution control and environmental health effects.